TELESCOPE MAKING 23

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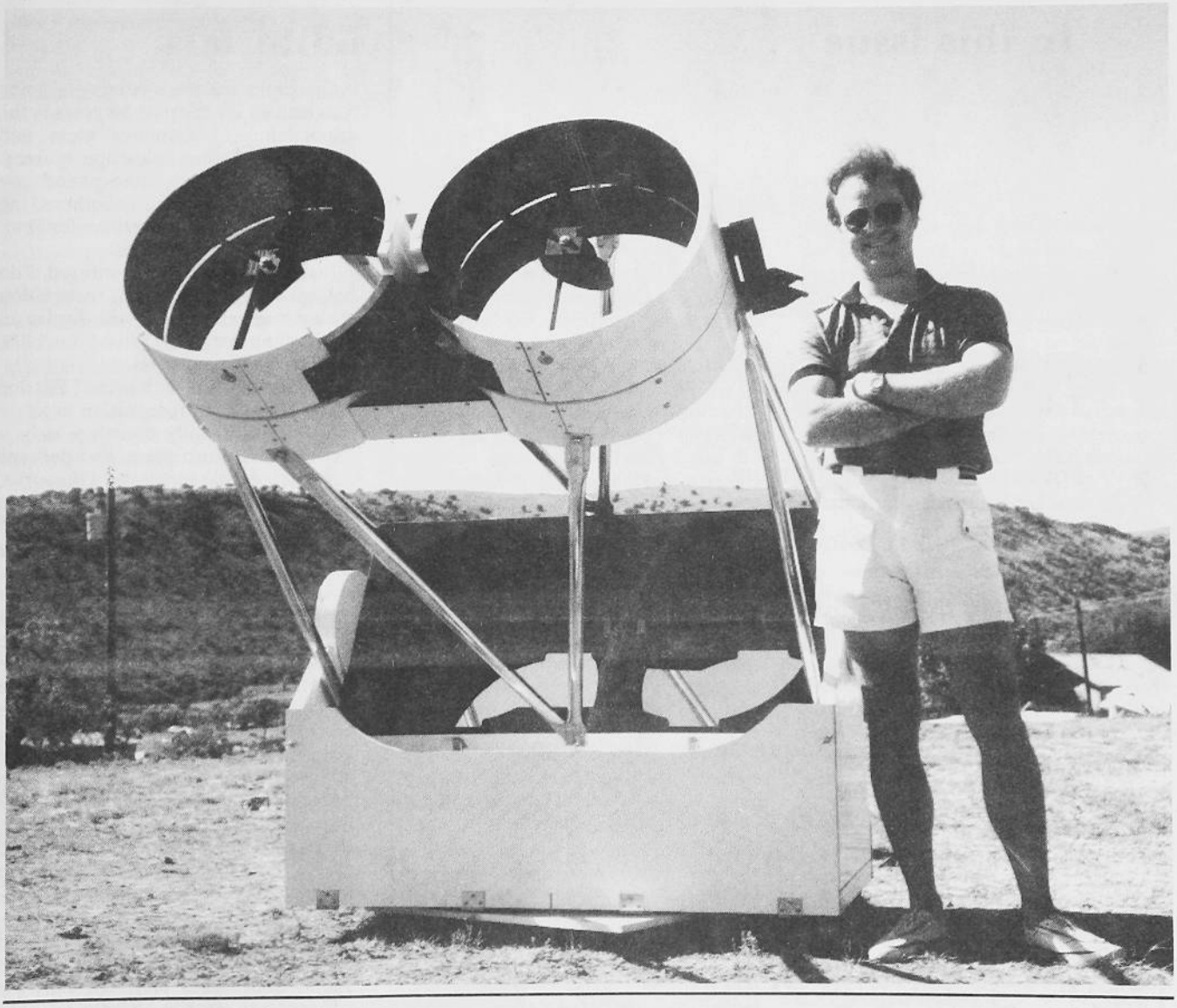

Lee Cain's 17.5" Binocular at the Texas Star Party

TELESCOPE MAKING

The magazine *for, by,* and *about* telescope makers!

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Editorials

One of the reasons I've enjoyed going to meetings for the past 50 years is the opportunity to exchange ideas and views with fellow telescope makers. However, over this same period one thing that has consistantly bothered me has been the open competition for First, Second, and Third places.

Just so no one will be confused, I do believe that some form of recognition should be given to those who display an outstanding telescope. What I don't like is ranked prize contests.

So what's wrong with prizes? For one thing, prizes limit recognition to a few individuals. Usually there are only a first, second, third prize, and perhaps a few honorable mentions. Of course, giving a greater number of prizes solves the problem, but who wants to admit winning an 8th prize? It's better not to win at all.

Another problem is that the nature of the prize-giving system limits what the judges can look at. Prize contests are perfect for things that are fundamentally the same and can be ranked — like prizes for kids who've grown the biggest pumpkins. Telescopes present far richer opportunities for recognition than pumpkins do. Comparing telescopes is like comparing apples, oranges, bananas, and fruitcake. Which should win? A contest forces the judge to reduce the whole range of flavors to 1, 2, and 3.

If one examines prizes that have been awarded in prize contests over the years, it becomes apparent that the winners are usually those who have spent the greatest amount of money or have the finest machining facilities! The fellow with limited resources is literally

frozen out of the competition — yet his display may prove of greater value to more people than the fancy one which captures the prize.

It has always seemed a shame to me that recognition has so often gone to a display that few could duplicate, while the simple, ingenious, and widely-imitated often went unrecognized.

Back in the late 60s, at a meeting of the Apollo Rendezvous and Telescope Fair at Dayton, Ohio, an amateur displayed an instrument that was a beauty to behold. It also happened to be on the shakiest mount I have ever seen. Naturally it did not get any recognition. I later happened to hear that builder saying, "That's all right. I'm going to Stellafane and get a first prize. That'll show them!". He did go later that year and, fortunately, won nothing with so poor a mounting. But the story underscores the problem with prizes: prizes encourage the wrong kind of thinking. Not once do I remember hearing anyone say, "I'm going to Stellafane to help my fellow amateurs."

What happens without prize contests? Let's face it: everyone, and I mean everyone, likes recognition from his peers. Anyone who denies it is kidding himself. But why not eliminate the prizes and bestow recognition via certificates of merit.

Merit awards allow an award committee (not "judges") to highlight each person's unique contribution to the meeting and the art of telescope making. Merit awards are unranked — there is no first, second, and third. Telescope making then offers all TMs an equal opportunity to make interesting and important contributions to the field.

There are many benefits from this approach. I personally feel that the greatest benefit is the elimination of fixed categories of judging. Once judges do not have to "judge" an instrument as a whole, but are free to recognize an interesting accessory or a new idea that by prize standards would not be a winner, they become *evaluators* instead of judges, looking for good ideas, excellent craftmanship, or anything about that display which is noteworthy. This method, incidentally, works for astrophotos as well.

I suggested this approach years ago for the Apollo Rendezvous and Telescope Fair in Dayton, and am pleased to note that they adopted this method and have continued to use it. In the early 1970s at the RTMC, I suggested this idea again, and my good friend Clifford Holmes switched to awards, rather than prizes, for subsequent Riverside conventions.

Other groups which adopted the Merit Award system are the Texas Star Party, Astrofest, and the Peoria Society's ALCON 1982. I earnestly hope that the Astronomical League's Board of Directors will in the future encourage member societies to adopt this method of recognition at meetings.

A certificate might take a form such as:

> "The [name of the society or meeting] awards this Certificate of Merit to [recipient's name] in recognition of the contribution to the field of telescope making for [description of merit award]."

The award is signed by either the officers of the club or the committee that evaluated the displays.

The citation should avoid adjectives that suggest one display is "better" than others. Words such as "first" and "best" can be avoided; there are plenty of good adjectives — outstanding, excellent, unusual, clever — that satisfy the ideals of the award and make those receiving them happy. As a side benefit, these adjectives are often more accurate in describing why the award was given than the comparative adjectives.

I would like to ask those who will be participating at future meetings, either as judges or as participants, to push for a policy of equal recognition. Let us make the telescope making and astronomy groups the first nationwide groups to make this important step.

Hopefully, we will find that in the future, when amateurs meet, they will go with the thought, "I hope that what I bring to display benefits my peers and friends regardless of whether or not I receive an award or a prize." Those who do will achieve the state of Perfect Telescope Nut! — *Bob Cox*

This is another of TM's "jumbo" issues, the magazine having swollen from the default value of 56 to 64 pages. Part of this is due to running my article on three big meetings all together instead of spreading it out one per issue as we normally do. And part of our size comes from a lengthy piece on the La Palma observatory, which is a new kind of article for TM. All in all, it's a rather unusual issue. Please let me know if you like this sort of thing once in a while. We'll be back to our more usual fare with the next issue.

Another reason this TM's big is business is booming for the Blue Pages. They're up to 10 pages. Take a look — you'll find ads which you might have noticed in the glossies. The nice thing is that increased advertising has resulted in more pages for articles. Now comes a request: advertisers must know that their ads produce. When you next order something, you can help TM by mentioning that you're a *Telescope Making* reader. Let them know you read their ads in *Telescope Making*.

Now, back to the big IAPPP, Riverside, and TSP article. Whenever I've written a meeting report, I've had to leave out a lot — telescopes that should have been mentioned, people who should have gotten credit for this, that, or the other thing, and things that I simply didn't see. I've also spelled names wrong, gotten awards mixed up, moved people to distant cities they don't live in, and even garbled technical details of telescopes. Often I don't find out about it until the next year — then I meet someone who says, "You got the size of my telescope wrong." "Oh?" I'll say, "Did you write and let me know about it?" They'll say, "It's no big deal," or, "I didn't get around to it," or some such. Well, maybe it doesn't matter, but I would appreciate the chance to correct such errors when they do happen, so don't just sit there feeling bad about it — drop me a postcard!

Finally, I would like to thank all the people I didn't mention for taking the time to talk with me, and thank all the people at all the meetings I've been to, who, ever-so-promptly or not-so-promptly, have sent articles and pictures to TM. Bob Cox and I appreciate the effort you put into preparing stuff for publication, and hope that you will continue to find us reasonably responsive (though it may take a month or two before you get that postcard saying we've gotten your article) and will continue to enjoy the material we select for the pages of TM.

Sincerely,

Richard Berry

Telescopes and Tombaugh

The Telescope Making Genius of the Discoverer of Pluto

Were it not for a 9-inch f/9 telescope and a handful of planet drawings, Pluto might not have been found back in 1930.

We have all heard about Clyde Tombaugh's singular accomplishment 54 years ago, using a 13-inch camera, a well-organized search program, and a lot of determination. But this search began not with the lens on Mars Hill, but much earlier, with a reflector on a farm in Kansas. It was his homemade telescope, which he used for his drawings of Mars and Jupiter, that prompted V. M. Slipher to inquire of Tombaugh, "Are you in good physical health?" and offer him the planet-seeing position at Lowell Observatory.

Still active and optically perfect after weathering half a century, the 9-inch still provides unparalleled views of the planets Clyde Tombaugh loves so much. "I don't use domes and I don't leave telescopes inside," he explains with a proud look around his telescope-filled yard. "I want them outdoors where I can use them!"

Standing in Tombaugh's yard is the most massive and unusual 16-inch telescope I have ever seen. Unprotected for the last 23 years, this telescope doesn't merely await the night sky — it *challenges* it to appear. Although construction was not begun until 1960, he dreamed it up in 1938 and obtained glass disks for it in 1941; indeed, he had already begun grinding the primary when Carl Lampland came down to tell him that the Japanese had just bombed Pearl Harbor. The ensuing war put an early end to the planet search, but not to the telescope.

Of the 1500 hours Tombaugh spent on the project, at least 100 were on the mirror alone. The massive tube contains one ton of steel. "I drilled through the equivalent of *twenty feet* of steel for the bolts. And I used only two sets of drills during the whole project. Always kept the drills sharp so that they would never get hot."

So this is a telescope to be approached with awe and respect, as the observer mounts a tall (*very tall*) platform and approaches the eyepiece.

In my case, I approached the eyepiece with trepidation and fright. Certain of falling off at any moment, I called down to Dr. Tombaugh that I might be unable to descend — ever. "But we'd have to send food up to you with a pulley!" Clyde called back. That's okay — the planets would provide good company.

Eventually, when my fears calmed and were instead replaced with admiration at the sheer uniqueness of this mount, Clyde joined me and removed the "covers" from all the telescope's optical surfaces.

Most of these covers were old, rusted tin cans which obliging manufacturers had apparently made to the exacting specifications of this huge telescope. The cover for the main mirror is held on with a long metal rod so that there is no chance of removal by weather, vandals, or cats.

This is a telescope for the planets. We cannot use it to gaze at the boulevards of stars that comprise M-13, or to admire the dark lane crossing M-82. This mighty reflector can point only toward the clear portion of sky to the south, so that it spends its time revelling in the planets. And on this night we began with Saturn. I looked through the 8mm eyepiece, and greeting me in the field (which at 524x, exactly matches that of Lowell's 24-inch refractor) was the sharpest, most dramatic view of Saturn I have ever seen. I looked at that remarkable image in silence, then . . .

"Would it be possible," I asked hesitantly, "to see the spokes?"

"Quite possible!" was the answer.

"Good," I replied with relief, "for I think I just saw some."

"But you know, David, that Saturn is lighter than water."

"Yes."

"And that it would float in a bathtub, if one were large enough."

"Uh huh."

"But would it leave a ring?!"

Perhaps I was just imagining that the great telescope shuddered with me as we both became victims of another famous Tombaugh pun.

But for all its incredible size and capability as a 16-inch, this telescope is unsatisfied with being *just* a 16-inch. Housed in the same tube is an 18-inch f/6 primary that the astronomy department at New Mexico State had asked him to test.

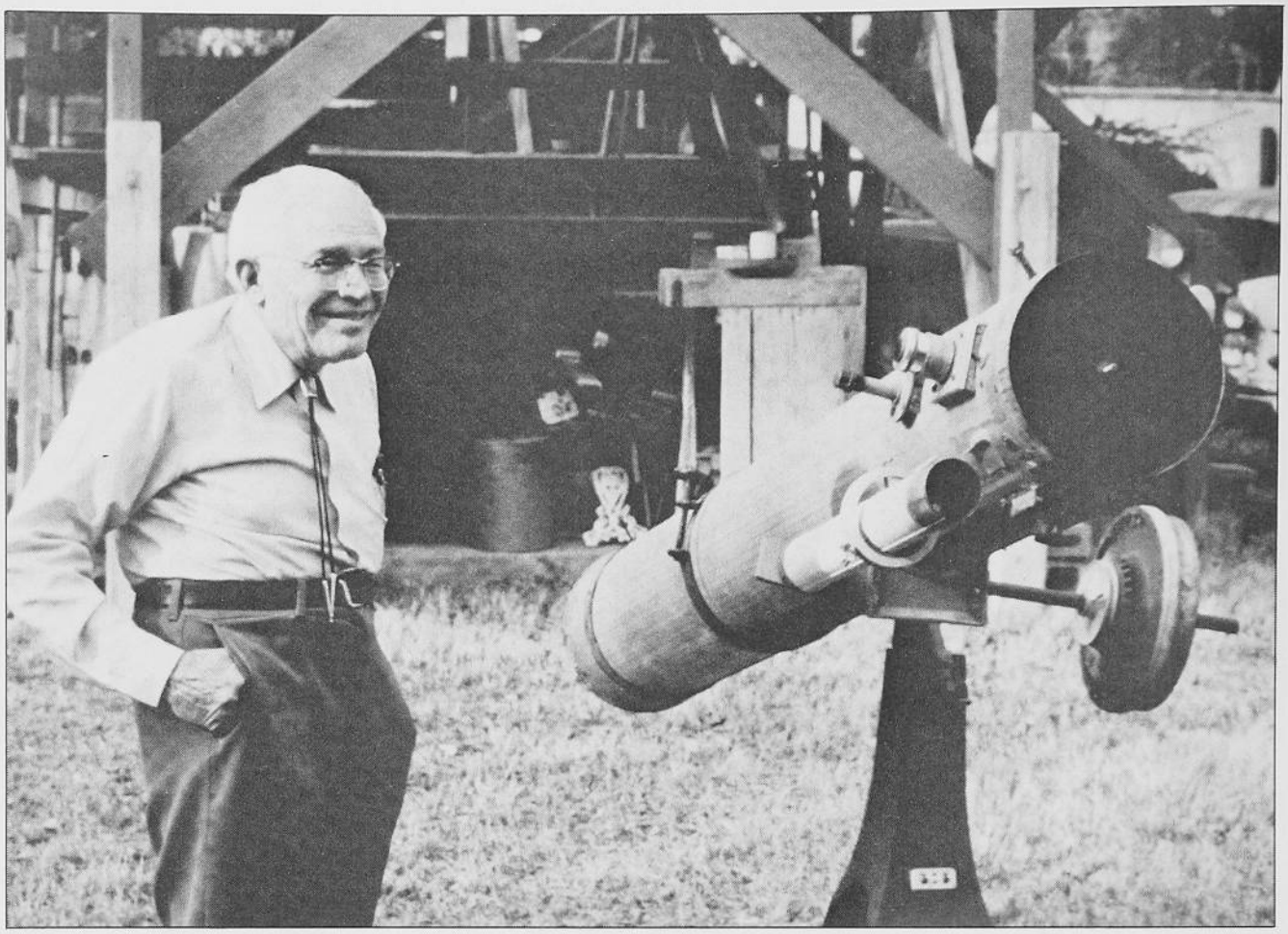
I have never seen a telescope that looks or behaves even remotely like this one. The 16-inch and its shorter focus 18-inch mate form a telescope combination that is a monument to the uniqueness and original thought of the man who discovered Pluto. I asked him about this once, about his special qualities ...

"For 50 years," he answered, "I guess I've been a Plutocrat."

Clyde's first telescope was an 8-inch f/7 that was built in 1926. He cut the mirror out of a 10-inch f/5 that he had salvaged. A year later he built a telescope for his uncle, but this instrument has apparently not survived. The 9-inch followed in 1928, and soon after that he directed his considerable energy to finding planets.

In 1933, Clyde Tombaugh built what appears to be the first rich-field telescope in the United States. It is a

It s-w-a-y-ys, but the scaffolding provides a steady way to observe with the 16-inch. "How did you build this all by yourself?" I asked Dr. Tombaugh. "One plank at a time!"



The telescope that led to Lowell Observatory and Pluto: the 9-inch f/9, built in 1928.

5-inch f/4 reflector which survives today as a finder, riding atop the mighty 16-inch. But "I would never make a telescope that short now," he advises, "not even an f/5. I would not want anything faster than f/6; otherwise, you simply get too much coma at the edges." An interesting comment from the man whose first RFT is pictured on page 639 of *ATM-2*.

The following year Tombaugh returned to long-focus mirrors with a 5-inch mirror. Since he was no longer using his first 8-inch from 1926, he simply cut the new mirror from the old blank with a coffee can. The other scopes that year were 12-inch mirrors of two different thicknesses. The thicker one turned out slightly over-parabolic.

"I was truly surprised at the performance of the thin 12-inch," Clyde recalls. He designed a firm support for it using eight ¾-inch strips of pine wood, all the same widths and exactly parallel to each other. Cardboard and a small piece of carpet sat on top of the wood, with the thin mirror resting comfortably on top of the carpet.

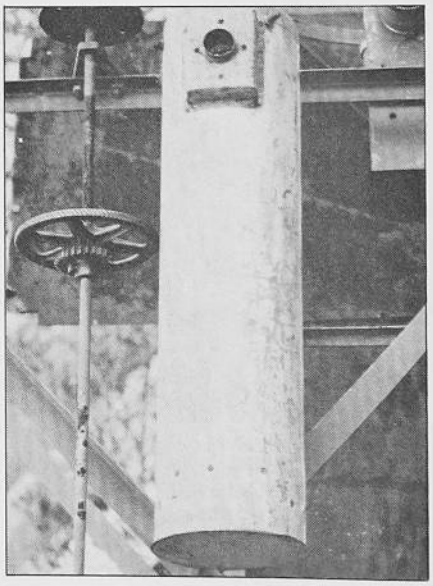
In 1944, he completed a 10-inch, a telescope that now watches the stars on a considerably modified Dobsonian-type mount. The azimuth motion rides on an eight-inch diameter aluminum disk that rides against a plate, also made of aluminum, that is bolted onto the bottom of the Dobsonian fork. Aluminum on aluminum. No oil needed, and the friction is perfect!

Throughout this period, Clyde had been at Lowell Observatory. After the discovery of Pluto in 1930, the decision was made to continue the planet search, so between 1929 and 1945, he checked some ninety million star images with the blink comparator at Lowell. Ninety million? Clyde looked up thoughtfully. "Plus or minus one million," he added helpfully.

But *ninety million stars*?

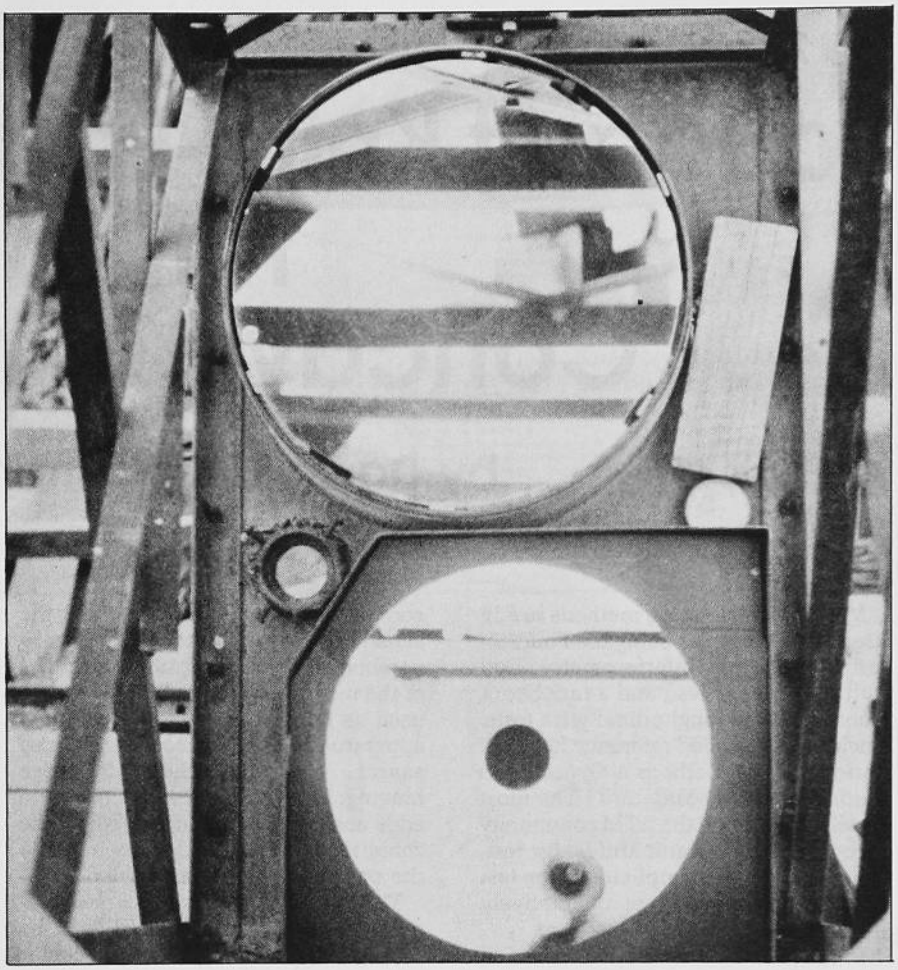
"Yes. That's right. The national deficit of the United States government is now $1500.00 for every star image I looked at during those years!"

On one occasion Gerard Kuiper, founder of the Lunar and Planetary Laboratory in Tucson, told Tombaugh that "your achievement in finding Planet X was truly significant, but hardly as vital as what you did *not* find in all those years of searching." Other than Pluto, Tombaugh is confident that there was no planet, 15th magnitude or brighter, within some 40 degrees on



The old 5-inch f/4 telescope, perhaps the first RFT in the US, is seen here mounted as a finder for the 16-inch.

16 and 18-inch mirrors side by side at the bottom of the metal framework.



each side of the ecliptic during the years he searched.

In 1960, after completing the monstrous 16-inch, Tombaugh began a 12-inch for the north dome at Tombaugh Observatory at NMSU. In 1978 he completed a 6-inch Cassegrain, 38-inch focal length.

The 18-inch that rides parasitically under the 16, and a 20-inch f/8 made from a thin disk, complete the collection. "Thin mirrors are fine," Tombaugh notes, but he adds, "provided that they are carefully supported."

In November 1966 Dr. Tombaugh stood out in the yard on the west side of his house. "In two hours of watching, I estimate that I saw 100,000 Leonid meteors. I could count up to *four dozen* contrails at once!"

A year after our interview, this extraordinary planetary astronomer visited Tucson to lecture about Pluto. We took him to see the special work being done on professional telescopes here in Telescope City, and he got a chance to see some of the ATM work also being done here. Whenever telescopes were mentioned, his eyes would light up with a special gleam. Clyde Tombaugh is at home with telescopes.

I noticed Tombaugh's influence also in the telescopes he chose for the expanding astronomy department at New Mexico State. The main planetary telescope on nearby A mountain is one of the finest small professional instruments I have seen.

In addition to his planet and 36 optical surfaces, what else is Dr. Tombaugh known for?

In 1932, he discovered that NGC-5694 was a globular cluster — and it later turned out to be one of the most distant known globulars, way over on the far side of the galaxy. The cluster was found two years after the resumption of the planet search, and its discovery was almost as significant for stellar astronomy as Pluto had been for planetary science.

In the autumn of 1936, Tombaugh discovered a huge cloud of some 1800 galaxies spread through the constellations of Pegasus, Andromeda and Perseus. Covering 300 square degrees of sky, this remote supercluster is an impressive byproduct of a search for new solar system objects!

To these major finds we can add a few smaller galaxy clusters, and within our own galaxy, five open star clusters.

Other solar system objects? A few. He discovered 775 asteroids and one comet.

Looking at and through Tombaugh's collection must be like discovering some hitherto unknown Egyptian treasure. This man is known for discovering Pluto, and perhaps this has detracted from the acclaim he also deserves as a maker of telescopes. Had his reputation not been dominated by Pluto, Tombaugh might well be remembered as one of the greatest telescope makers of all time, a craftsman in the tradition of William Herschel, Rosse, and Clark.

Clyde William Tombaugh is as skilled and imaginative a craftsman as he was a dedicated searcher. A family of unique telescopes, as well as a small world at the fringes of our solar system, celebrate the success of this outstanding astronomer. And the largest telescope sits unprotected in the yard, longing for each night's placid start. "Telescopes belong outside, uncovered — except for optics — to weather and sky," says Clyde Tombaugh as he moves the monstrous tube; "this way they get to see the stars."

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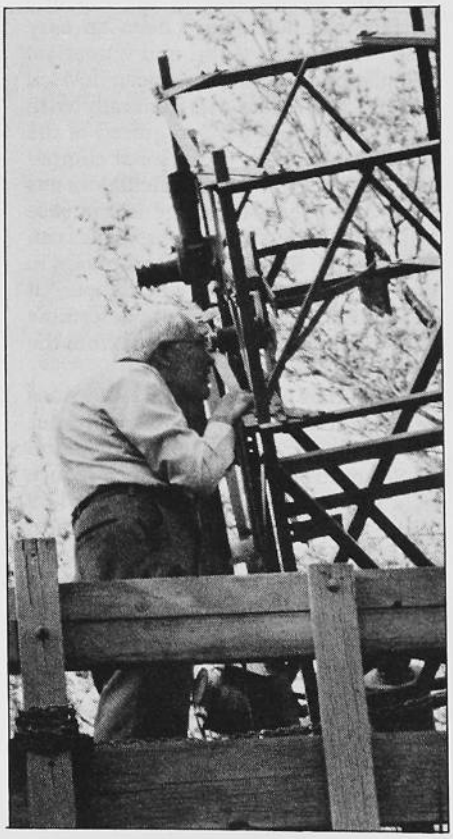


Foucault Knife-Edge Testing for Concave Mirrors

by David E. Stoltzmann

Many mirror testing methods are in use today, examples being the Foucault test, Ronchi test, interferometry, Dall null test, caustic test, and a number of transverse and longitudinal wire tests. (Incidentally, a good reference for these various testing methods is *Optical Shop Testing* by Daniel Malacara.) The most widely used test in the ATM community is, by far, the Foucault knife-edge test. This is due to the simplicity of the test and the relative ease of qualitatively interpreting the shadow patterns.

In the past the quantitative reduction of the knife-edge readings to produce an accurate wave rating of the mirror's surface has not always been an easy task. Various graphical and numerical calculation schemes have been devised to reduce the data, but generally with a fair amount of labor required of the ATM. The advent of personal computers and programmable calculators has provided a real advantage in the ease with which the knife-edge readings can be reduced. By using the computers to perform the laborious calculations, it becomes a routine matter to determine the surface quality of a mirror from the knife-edge readings.

The author has written three versions of essentially the same computer program in BASIC, FORTRAN, and TI-59 keystroke language, which reduce data from the Foucault test. The TI-59 and BASIC versions use three zones, while the FORTRAN version can use up to five zones. There is no inherent reason why the BASIC version, for example, also could not handle five zones, but more about this later. For now, we will confine the discussion to the three-zone version of the program.

The program uses longitudinal aberration measurements (Foucault knife-edge readings) of a concave mirror tested at its center of curvature, to compute the wavefront error of the actual surface relative to the best fitting paraboloid. The data from three zones of the mirror (e.g., 30%, 70%, 90%) are used as input. The knife-edge testing apparatus is assumed to have a fixed source, with only the knife edge moving. If the tester has both the knife edge and source moving together, the zonal measurements used as input to the program should be doubled.

The longitudinal aberration measurements used as input need not be adjusted for the location of the center of curvature of the central zone. Only the *differences* between the zonal measurements are used by the program, and thus the readings can have an arbitrary offset from the paraxial center of curvature. The program's convention is that the knife-edge positions increase in a positive direction away from the mirror (which is the normal case for testing paraboloids, ellipsoids, and hyperboloids). Only oblate spheroids would have decreasing zonal readings. Figure 1 depicts the testing scenario.

METHOD — A perfect paraboloid focusing light from infinity has no longitudinal aberration. However, when the light source is brought to the paraboloid's center of curvature, as is done in the Foucault test, each radial zone of the paraboloid produces a measurable amount of longitudinal aberration (knife-edge readings). Other conic sections such as hyperboloids, ellipsoids, and oblate spheroids also show longitudinal aberrations; only the sphere shows no longitudinal aberration when tested at its centure of curvature.

By measuring the longitudinal aberration for a set of three zones, three simultaneous polynomial equations can be set up, of the form:

$$LA_1 = ay_1^2 + by_1^4 + cy_1^6 - \delta_1$$

$$LA_2 = ay_2^2 + by_2^4 + cy_2^6 - \delta_1$$

$$LA_3 = ay_3^2 + by_3^4 + cy_3^6 - \delta_1$$

in a manner similar to Smith's treatment on page 293 of *Modern Optical Engineering*, (W. Smith, McGraw Hill, 1966). The LAs are the knife-edge readings for the three zones, the ys are the semi-apertures of the zones, and δ_1 is a constant offset of the LAs to the actual paraxial center of curvature. For a *smooth* mirror, $\delta 1$ can be determined from the inner two zones:

$$\delta_1 = \frac{y_2^2}{y_2^2 - y_1^2}\left[LA_2 - LA_1\right] - LA_2$$

This relationship is exact for a perfect paraboloid, and is an excellent approximation for other smooth conic sections.

The program uses Cramer's rule to solve for the constants a, b, and c, thus providing a single equation for LA as a function of y.

By integrating this equation of LA(y), the wavefront optical path difference (OPD) is determined:

$$OPD = \frac{1}{R^2}\int_0^Y y\left(ay^2 + by^4 + cy^6 - \delta_1\right)dy$$

$$OPD = \frac{-y^2}{2R^2}\left(a\frac{y^2}{2} + b\frac{y^4}{3} + c\frac{y^6}{4} - \delta_2\right)$$

where:

R = mirror's radius of curvature (paraxial)

δ_2 = defocus from paraxial focus required to minimize the OPD

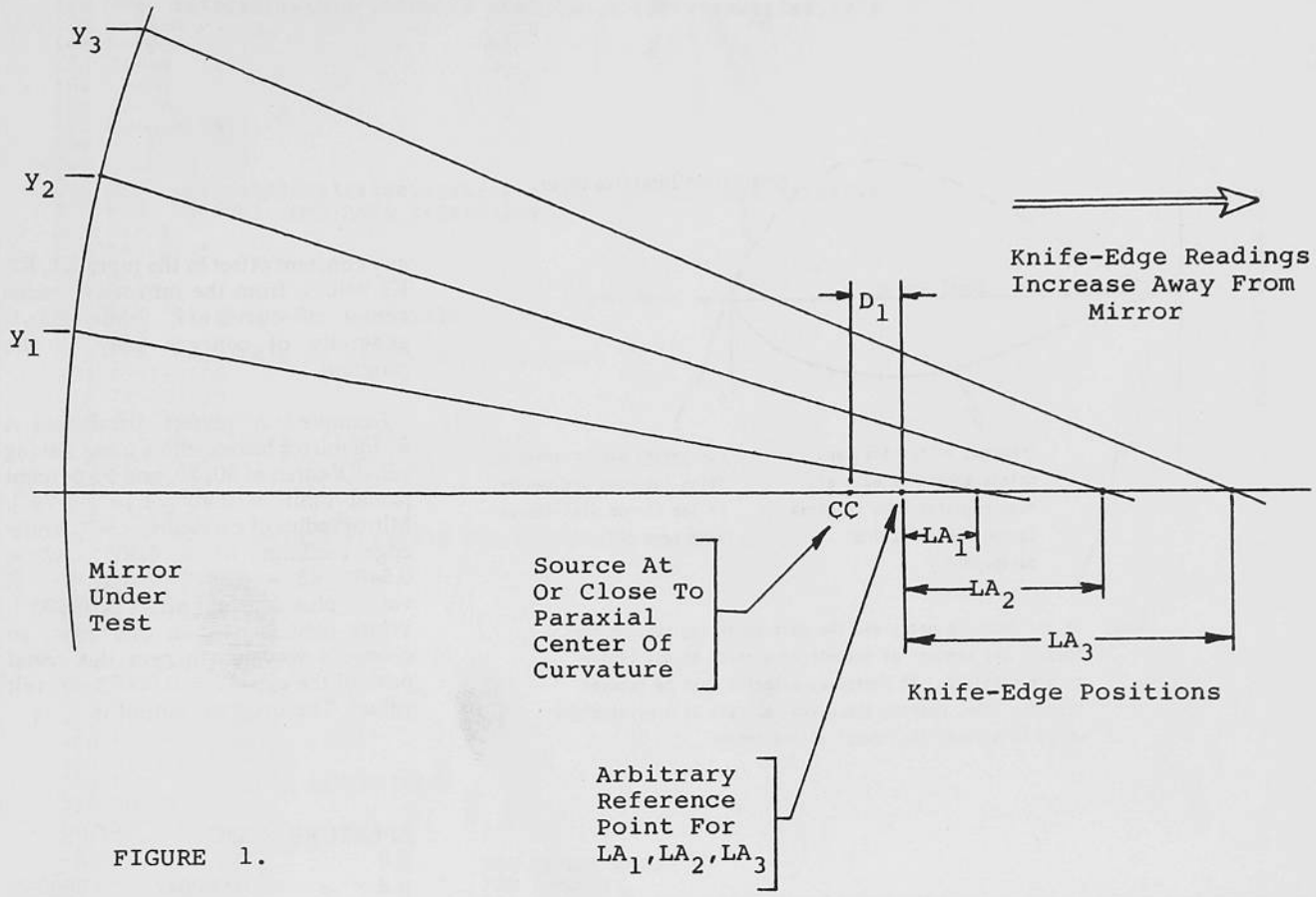


FIGURE 1.

The defocus, δ_2, sets the marginal ray OPD to zero. (The OPD across the wavefront changes with the amount of defocus, but is minimized when the marginal ray OPD is zero, i.e., when a reference paraboloid contacts the actual wavefront at the center and edge of the mirror aperture.) The value for δ_2 to accomplish this is given by setting the previous equation for OPD to zero at y = y_o = semi-aperture of the mirror:

$$\delta_2 = \frac{a}{2} y_o^2 + \frac{b}{3} y_o^4 + \frac{c}{4} y_o^6$$

Thus having determined a, b, c, and δ_2, the OPD of the *measured* wavefront can be compared with the OPD which would be produced by a *perfect* paraboloid (when knife-edge tested at its center of curvature). The OPD of a perfect paraboloid, assuming a stationary source and moving knife edge, is given by:

$$OPD_{paraboloid} = \frac{y^2}{4R^3}\left(y^2 - y_o^2\right)$$

or for a general conic section:

$$OPD_{conic} = \frac{-ky^2}{4R^3}\left(y^2 - y_o^2\right)$$

where k = conic constant = $-(\text{eccentricity})^2$.

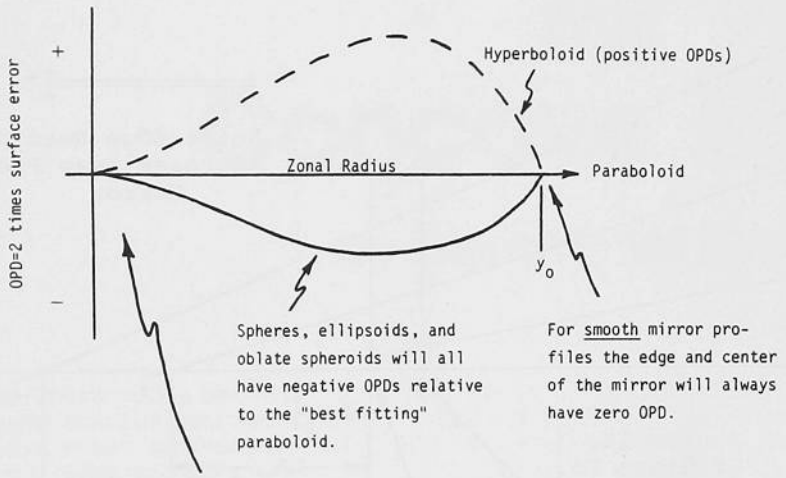
By subtracting the OPD of the parabola from the measured OPD, the actual *wavefront* error of the mirror under test is produced. The program computes this wavefront error at $y_o/10$ intervals across the mirror's semi-aperture. The maximum range of values so produced gives the peak-to-peak *wavefront* error of the mirror. The actual mirror *surface profile* error is half the wavefront error.

By plotting the OPD values listed by the program (or half these values for the surface figure errors), the amount and location of glass removal can be seen for the next polishing stage of correction of the mirror's surface figure, as shown in fig. 2.

USER INPUT — The input data required by the program are the location of the three zones (expressed as percentages of the diameter of the mirror), the diameter and radius of the curvature of the mirror, the measured knife-edge readings (longitudinal aberrations), and the wavelength of light used. Note that for paraboloids, ellipsoids, and hyperboloids, the knife-edge readings increase in a positive direction away from the mirror. The opposite is true for oblate spheroids. In the BASIC version of the program, these input values are given the mnemonics:

Z1, Z2, Z3 = relative zone locations, e.g., 30, 70, 90 percent
K1, K2, K3 = knife-edge readings corresponding to zones Z1, Z2, Z3
D = mirror diameter
R = mirror radius of curvature

The user inputs are at the beginning of the program in lines 130 to 200, and the dimensions are assumed to be in inches. Four other values are also under user control, in lines 230 to 260.



Note: If the OPDs are negative, the next polishing session must "deepen the center" of the mirror surface to get closer to a paraboloid. If positive, material must be removed from the edge, meaning the actual surface is a hyperboloid which is already too "deep" at the center.

However, the default values given in the program listing will generally suffice for the majority of the mirrors to be tested:

C1 = −1 = conic constant of reference surface (parabola = −1)
W = 0.000022 = wavelength of light in inches (units consistent with other inputs)
N = 10 = number of points for output data at D/(2N) intervals
E = 0 = linear obscuration

If units other than inches are input, just remember to be consistent with all the dimensional parameters, and change the wavelength W to the same units. If the mirror under test is to be other than a paraboloid (for example, a hyperboloidal primary of a Ritchey-Chretien Cassegrain), then set C1 equal to the conic constant for that desired surface.

The obscuration parameter E, defined as the ratio of the secondary diameter to the primary diameter, should be left zero for almost all routine mirror testing. Eventually, however, the mirror could actually have a central obscuration in the finished telescope. By obscuring this central portion of the mirror, a slightly better wavefront performance is obtained at a slightly different focus position (which the user at the eyepiece automatically sets). Thus, for a completed mirror, the actual wavefront performance including the effects of an obscuring secondary can be obtained. The improvement in the wavefront is more pronounced for poorer mirrors (large OPDs) and large obscurations. This improvement is only in the peak-to-peak value of the OPD, and does not reflect the actual reduction in contrast (MTF) which also accompanies a central obscuration. Most likely, setting E to anything other than zero will only be for the real purist ATMs, or systems with large central obscurations.

The output of the program is a listing of the surface error and wavefront OPD (twice the surface error) in wavelengths at N zones of the mirror's semi-aperture. In addition, the computed constants a, b, and c are printed, as are the defocus terms D1 and D2. D1 is a measure of any constant offset in the input K1, K2, K3 values, from the mirror's paraxial center of curvature, while D2 is generally of concern only to the program.

Example 1: A "perfect" paraboloid. A 6″ f/8 mirror tested with a mask having zones located at 30, 70, and 93 percent (zonal radii = 0.90″, 2.10″, 2.79″). Mirror radius of curvature = 96″. Knife-edge readings: K1 = 0.508″, K2 = 0.546″, K3 = 0.581″ (that is, y^2 / R values plus constant offset of 0.500″). White light is used in the tester, so choose a wavelength near the visual peak of the eye, W = 0.00022 (default value). The program output is:

APERTURE	SFC	OPD
0.0	0.0	0.0
0.3	0.000047	0.000095
0.6	0.000181	0.000363
0.9	0.000377	0.000754
1.2	0.000588	0.001176
1.5	0.000747	0.001495
1.8	0.000774	0.001549
2.1	0.000602	0.001204
2.4	0.000236	0.000473
2.7	−0.000140	−0.000280
3.0	0.0	0.0

a = 0.0105436
b = 0.0000175
c = −0.0000034
D1 = 0.49945
D2 = 0.0473072

The output from the program confirms that this example is virtually a perfect paraboloid. The program has removed the constant offset of the knife-edge readings, indicated by the value of D1. The peak-to-peak error of the computed wavefront from an ideal paraboloid is found by locating the maximum excursions in the OPD output = (0.001549 − (−0.000280)) = 0.001829 waves or 1/546.75 wave. The small OPD error thus reflects the almost perfect input numbers chosen for this example.

```
100 REM  OPD FROM WAVEFRONT KE MEASUREMENTS
110 DIM M(9),M1(3)
120 REM  ************************ USER INPUT ********************
130 D=10
140 R=100
150 Z1=30
160 Z2=70
170 Z3=90
180 K1=0.011251
190 K2=0.061278
200 K3=0.101327
210 REM  ************************************************************
220 REM  DEFAULT CONSTANTS ***********
230 C1=-1
240 W=2.2E-5
250 N=10
260 E=0
270 REM  ******************************
280 REM
290 REM  CALCULATE D1 FROM FIRST TWO ZONES
300 Z1=Z1/100
310 Z2=Z2/100
320 Z3=Z3/100
330 D1=Z2*Z2*(K2-K1)/(Z2*Z2-Z1*Z1)-K2
340 REM  CORRECT FOR CONSTANT OFFSET
350 K1=K1+D1
360 K2=K2+D1
370 K3=K3+D1
380 REM  SETUP MATRIX ELEMENTS FOR COMPUTING DETERMINANT
390 Y0=D/2
400 Y2=Y0*Y0
410 M(1)=Z1*Z1*Y2
420 M(2)=Z2*Z2*Y2
430 M(3)=Z3*Z3*Y2
440 M(4)=M(1)*M(1)
450 M(5)=M(2)*M(2)
460 M(6)=M(3)*M(3)
470 M(7)=M(4)*M(1)
480 M(8)=M(5)*M(2)
490 M(9)=M(6)*M(3)
500 REM  CALCULATE DETERMINANT
510 GOSUB 2000
511 D3=S
520 REM  CALCULATE A
530 FOR I=1 TO 3
540     M1(I)=M(I)
550 NEXT I
560 M(1)=K1
570 M(2)=K2
580 M(3)=K3
590 GOSUB 2000
600 A=S/D3
610 REM  CALCULATE B
620 FOR I=1 TO 3
630     M(I)=M1(I)
640     M1(I)=M(I+3)
650 NEXT I
660 M(4)=K1
670 M(5)=K2
680 M(6)=K3
690 GOSUB 2000
700 B=S/D3
710 REM  CALCULATE C
720 FOR I=4 TO 6
730     M(I)=M1(I-3)
740 NEXT I
750 M(7)=K1
760 M(8)=K2
770 M(9)=K3
780 GOSUB 2000
790 C=S/D3
800 REM  COMPUTE D2 FOR MARGINAL OPD=0
810 D2=Y2*A/2+Y2*Y2*B/3+Y2*Y2*Y2*C/4
820 Y4=Y2*Y2
830 E2=E*E
840 E4=E2*E2
850 IF E=0 THEN 880
860 REM  MINIMIZE OPD IN THE PRESENCE OF CENTRAL OBSCURATION
870 D2=Y2*A/2*(1+E2)+Y4*B/3*(1+E2+E4)
871 D2=D2+Y2*Y4*C/4*(1+E2*(1-E4*E2)/(1-E2))
880 REM
890 REM  COMPUTE OPD OF MIRROR AND CONIC(PARABOLA)
900 N1=N+1
910 Y=0
920 IF E=0 THEN 940
930 Y=E*Y0
940 Y1=(Y0-Y)/N
941 PRINT "APERTURE","SFC ERROR","WAVEFRONT OPD"
950 FOR I=1 TO N1
960     Y2=Y*Y
970     O1=Y2/(2*W*R*R)*(A*Y2/2+B*Y2*Y2/3+C*Y2*Y2*Y2/4-D2)
980     O2=C1*Y2/(4*W*R*R*R)*(Y0*Y0*(1+E2)-Y2)
990     O3=O2-O1
991     IF E=0 THEN 998
992     IF I>1 THEN 995
993     O4=O3
995     O3=O3-O4
998     S3=O3/2
1000     PRINT Y,S3,O3
1010     Y=Y+Y1
1020 NEXT I
1021 PRINT
1022 PRINT "A","B","C","D1","D2"
1030 PRINT A,B,C,D1,D2
1040 GO TO 9999
1130 LIST
2000 S=M(1)*M(5)*M(9)+M(4)*M(8)*M(3)+M(7)*M(2)*M(6)
2010 S=S-M(7)*M(5)*M(3)-M(1)*M(8)*M(6)-M(4)*M(2)*M(9)
2020 RETURN
9999 END
```

Example 2: Wave rating a sphere. To find out how much a sphere departs from an ideal paraboloid, simply enter knife-edge readings of zero. (Remember a perfect sphere tested at its center of curvature has no longitudinal aberration.) Using the previous example, by setting K1, K2, and K3 to zero, the following output is produced by the program:

APERTURE	SFC	OPD
0.0	0.0	0.0
0.3	-0.005150	-0.010300
0.6	-0.019975	-0.039950
0.9	-0.042603	-0.085206
1.2	-0.069913	-0.139826
1.5	-0.097535	-0.195070
1.8	-0.119851	-0.239702
2.1	-0.129994	-0.259989
2.4	-0.119851	-0.239702
2.7	-0.080057	-0.160113
3.0	0.0	0.0

a = b = c = D1 = D2 = 0.0

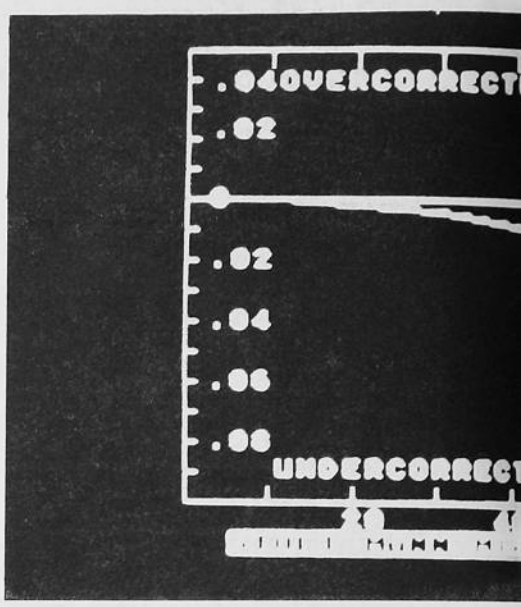
The maximum OPD departure is 0.260 waves or 1/3.85 wave, just slightly higher than the Rayleigh limit.

Example 3: Central Obscuration. Suppose the sphere in the previous example is used with a diagonal secondary mirror of 1.50″ diameter. The linear obscuration E is then 1.5/6.0 = 0.25. By running Example 2 again but with E = 0.25, the wave rating improves slightly:

APERTURE	SFC	OPD
0.75	0.0	0.0
0.975	-0.020064	-0.040127
1.2	-0.042603	-0.085206
1.425	-0.065710	-0.131420
1.65	-0.087079	-0.174158
1.875	-0.104012	-0.208024
2.1	-0.113414	-0.226827
2.325	-0.111795	-0.223590
2.55	-0.095272	-0.190544
2.775	-0.059565	-0.119130
3.0	0.0	0.0

a = b = c = D1 = D2 = 0.0

The maximum OPD departure now is 0.227 wave or 1/4.41 wave, just slightly under the Rayleigh limit. Note also that the mirror is evaluated only outside the central obscuration.



Example 4: Dall-Kirkham elliptical primary. A Dall-Kirkham Cassegrain (elliptical primary, spherical secondary) telescope is to have a 10″ f/5 elliptical primary, conic constant = -0.75. Figuring has just begun with the following knife-edge readings: K1 = 1.510, K2 = 1.573, K3 = 1.608 for the 30, 70, and 90 percent zones. The mirror surface is to be compared with an ellipse now, not a parabola, so we set C1 = -0.75. The program output is:

APERTURE	SFC	OPD
0.0	0.0	0.0
0.5	-0.006059	-0.012119
1.0	-0.023690	-0.047380
1.5	-0.051382	-0.102764
2.0	-0.086947	-0.173895
2.5	-0.127596	-0.255192
3.0	-0.169217	-0.338434
3.5	-0.204038	-0.408076
4.0	-0.215596	-0.431191
4.5	-0.169270	-0.339440
5.0	0.0	0.0

a = 0.0061544 D1 = -1.4958250
b = 0.0000766 D2 = -0.0722544
c = -0.0000053

A plot of the surface error is shown in fig. 3.

Thus the mirror is approximately 0.2 wave undercorrected from the desired ellipsoid. The next polishing session should continue to deepen the center. Note that D1 shows a large constant offset of the knife-edge readings of almost -1.5 inches. The interested reader could add D1 to each of the previous knife-edge readings, run the program again, verify the same wavefront performance, and thus show that the magnitude of any constant offset does not affect the results.

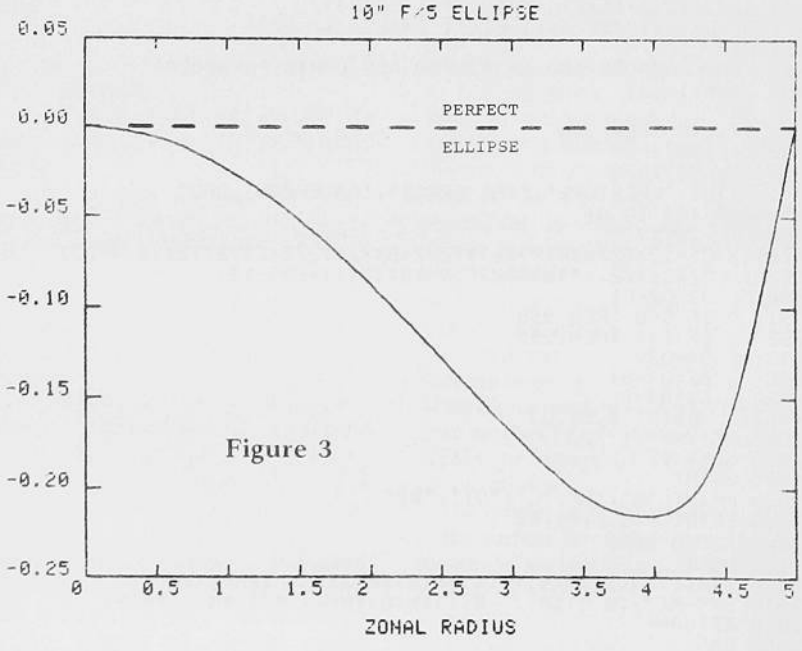
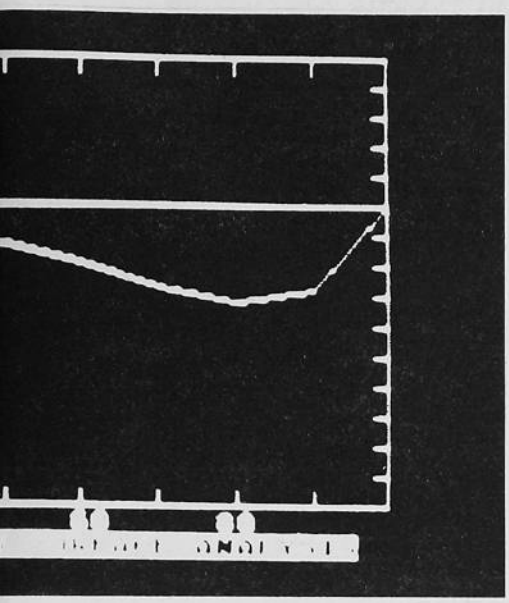
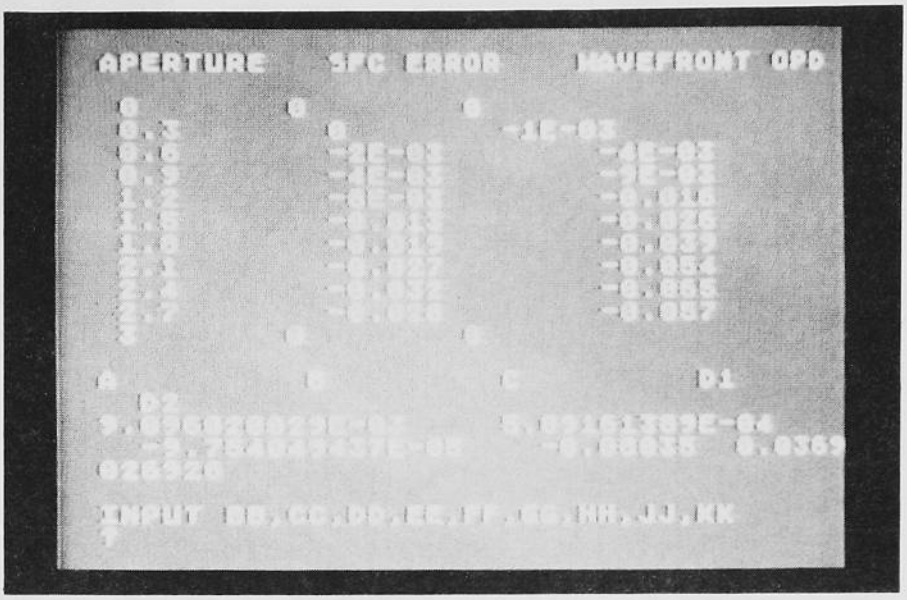


Figure 3





Above: Allyn Thompson's mirror. D = 6", R = 106", zones are 30, 70, and 93, with knife-edge readings of 0.088", 0.122", and 0.136".

Conclusions

This program eliminates the need for laborious hand calculations in determining the state of correction of a mirror, while providing for an accurate analysis of the mirror's figure. The ultimate accuracy, of course, depends on the accuracy of the input data. When using this program, many knife-edge readings should be averaged together for each zone.

It is very important to stress once again that the mirror be *smooth* before attempting to analyze the wavefront error with a program such as this. *Smooth* means no zonal irregularities. *Smooth* also means that generally three zones are sufficient to characterize the surface profile under test. The reason one sometimes tests large mirrors with more than three zones is that it can be difficult to get large mirrors really smooth, without zonal rings. Also, mirrors which depart significantly from a sphere (resulting in shadow patterns with very high contrast) could require more zones.

For readers desiring more than three zones to survey the aperture of a mirror, one can readily modify the program to include additional zones. The FORTRAN version of this program handles up to five zones, and anyone interested in a listing should contact Bob Cox. ■

```
120 REM  ************************ USER INPUT ****************
130 D=10
140 R=100
150 Z1=30
160 Z2=70
170 Z3=90
180 K1=0.011251
190 K2=0.061276
200 K3=0.101327
210 REM  ***************************************************
220 REM  DEFAULT CONSTANTS **********
230 C1=-0.5
240 W=2.2E-5
250 N=10
260 E=0
```

CHANGE REFERENCE SURFACE TO ELLIPSE, AND ERROR = 0.0

```
RUN
APERTURE          SFC ERROR          WAVEFRONT OPD
 0                 0                  0
 0.5               1.276706021E-5     2.553412041E-5
 1                 4.985306382E-5     9.970612764E-5
 1.5               1.07850227E-4      2.157004539E-4
 2                 1.816611817E-4     3.633223633E-4
 2.5               2.646366191E-4     5.292732381E-4
 3                 3.4729646E-4       6.9459292E-4
 3.5               4.131630241E-4     8.263260483E-4
 4                 4.298142303E-4     8.596284606E-4
 4.5               3.328444253E-4     6.656888506E-4
 5                 0                  0

A                 B                  C                  D1
D2
 0.0050029589892   -1.362482853E-7    9.396433469E-9
 5.074999999E-6     0.0625453071238


APERTURE          SFC ERROR          WAVEFRONT OPD
 0                 0                  0
 0.5               -0.0175653579398   -0.0351307158796
 1                 -0.068131965118    -0.136263930236
 1.5               -0.145311183864    -0.290622367728
 2                 -0.238454702455    -0.476909404909
 2.5               -0.332654397472    -0.665308794944
 3                 -0.408743612631    -0.817487225262
 3.5               -0.443301325612    -0.886602651224
 4                 -0.408661094861    -0.817322189721
 4.5               -0.272927098757    -0.545854197513
 5                 0                  0

A                 B                  C                  D1
D2
 0.0050029589892   -1.362482853E-7    9.396433469E-9
 5.074999999E-6     0.0625453071238
```

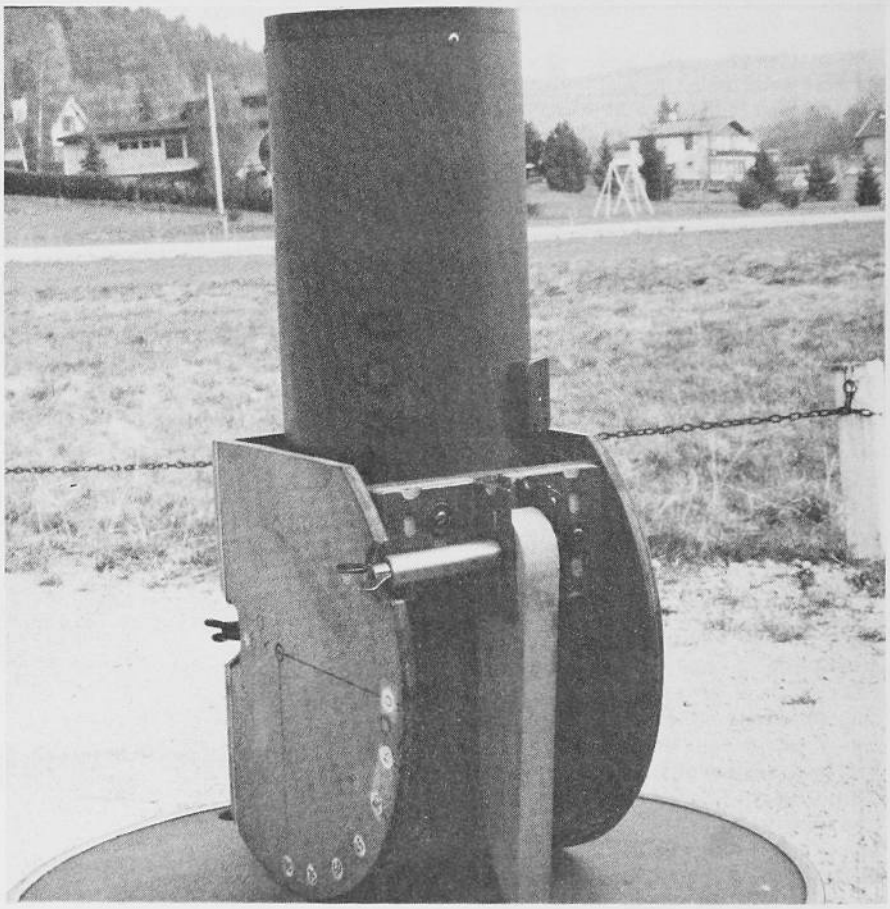
The 2DS:
A New Mounting from Poncet

The 2DS Poncet Mounting is an extremely simple, compact, and solid support for all portable telescopes. It is an alt-azimuth mounting that works by skidding on a smooth surface. The name I have given it comes from the diameter of the curved sides, which are twice the diameter of the tube; the "S" stands for skid. Although it is for astronomical telescopes, you can just as easily put it on an inside table or a solid garden table, and look at flowers, birds, and mountains.

The upper screw allows you to turn the tube or take the telescope off the mount. The lower screw allows you to clamp and move the skid — it is easily done, rolling the disks on the table. Note the shape and place of the screw and of the skid. When the screw is tightened, the telescope becomes a block leaning by three points on the table. When you add weight or lean on it, it simply becomes more steady. Graduations spaced at 15° intervals allow you to read off the altitude of the instrument. Looking along the edge of the box allows the observer to search for an object in the sky.

I have taken direct photos at the prime focus after looking through the ocular, and also by holding a 35mm SLR camera up to the eyepiece, keeping the 50mm objective on infinity, though a ring should be used for centering. The camera's automatic exposure meter will determine the exposure well enough for the Moon, the Sun through a Mylar filter, and for landscapes.

For solar projection, I turn the tube so the ocular is horizontal. The screen should be put in a shaded place. I use a screen about 10" x 10" recessed in a three-sided box having sides about 4" high painted black inside. The screen, of course, is white.



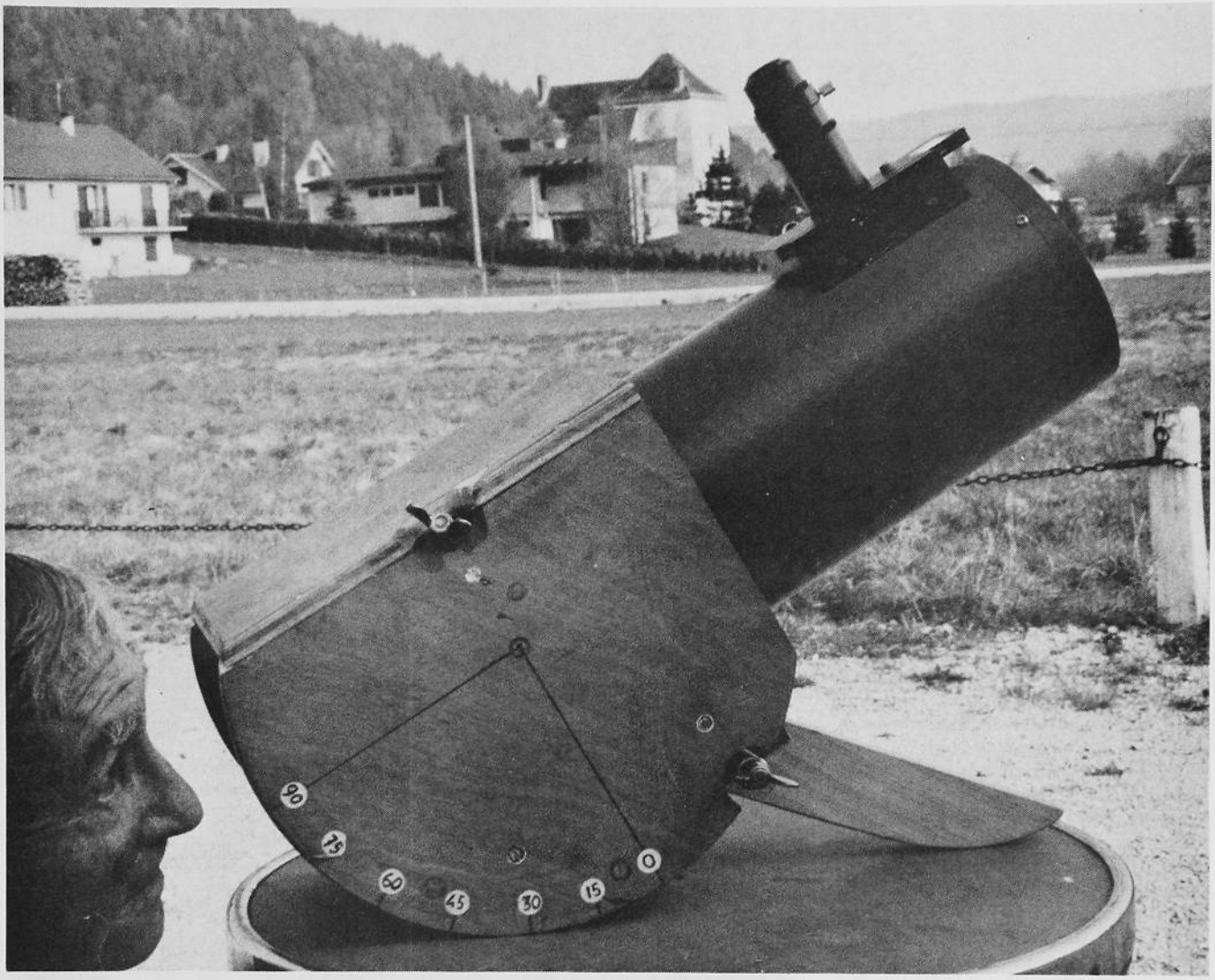
The whole thing works perfectly from the horizon right up to and including the zenith. Of course, tubes larger than that on the 140 mm f/3.5 telescope shown in the photos can be used directly on the ground. There are no problems of sliding because the curves are gentle, and no problems at any azimuth, either.

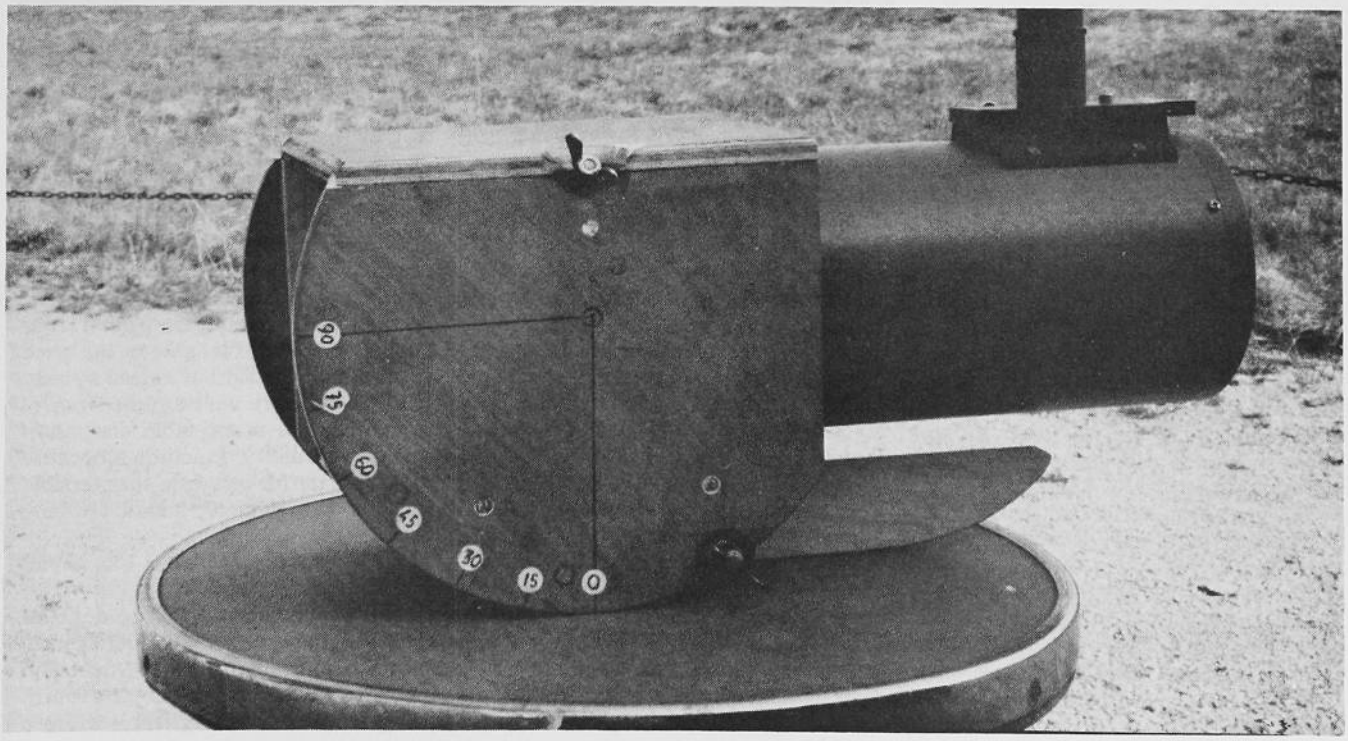
In some respects this mount is similar to Thompson's mount shown in TM#21, page 37, but differs in several important respects. The arcs are much longer than 90° and the ground supports more widely spaced, resulting in a safer and simpler solution. Incidentally, this telescope will be presented at the centenary of Besancon's Observatory.

All commercial rights are reserved on this design. Amateur astronomers, however, may construct a 2DS Poncet Mounting for personal use.

Adrien Poncet
39300 Crotenay
France

■


90
75
60
45
30
15
0


90
75
60
45
30
15
0

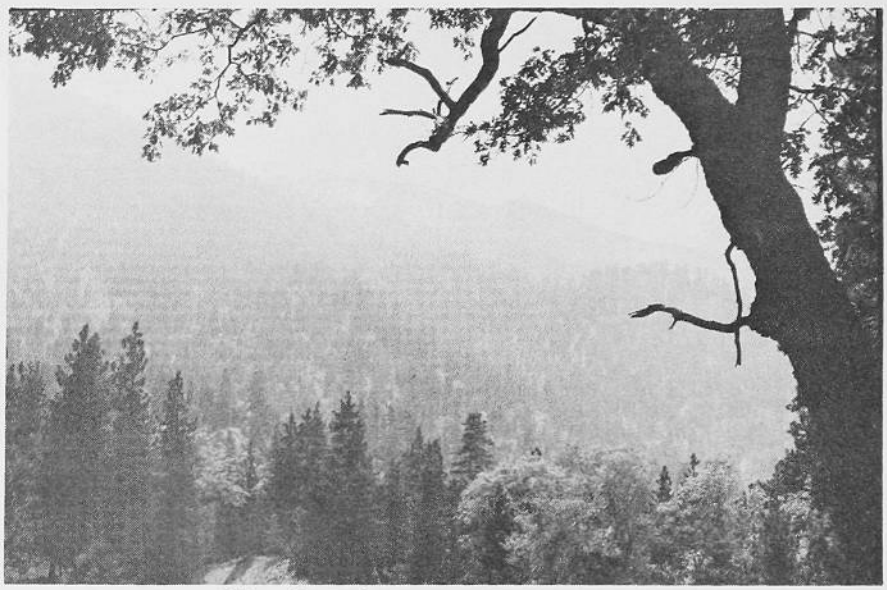
A Report on the 1984 Meetings of the IAPPP, Riverside Telescope Makers Conference, and The Texas Star Party

Big Bear Lake looked beautiful from two miles up, the deep blue of wind-whipped water cradled in its valley in the San Bernardinos, the mountains themselves sticking out like islands from the dingy tan clouds. Moments later the plane descended into the murk and down to Ontario (LA) airport.

I was two days early for the Riverside TMC, arriving for the third two-day Bear Bear IAPPP symposium. Ontario's citrus groves looked dry this year; the sun beat down. My rented car was a Colt. I loaded my bags and a box full of AstroMedia's doorprizes — TM backfiles — then started west on I-10. The air was heavy and hot on the freeway, the sky yellow. At Redlands I headed north on route 38, drove across the dry bed of the Santa Ana "River," then turned and drove up into the mountains.

38 rises quickly from the flat desert north of Redlands. The bright yellow flowers and pervasive scent of Scotch Broom were a relief from the smell of exhaust and harsh glare of the concrete freeway; all around the mountains loomed flat green against the dull blue sky, like a painted set. But a bit above 4500 feet, the road climbed out of the haze. The blue of the sky deepened; the air felt cool and clean. Big Bear Lake, as I drove past it, was an amazingly vivid shade of green, the more surprising since it looked so blue from the air. It was nice to be back.

This year I had decided to change my method of reportage. I have always carried a steno pad (just like a real reporter!) which I filled with copious notes as I talked to people and photographed telescopes. Then, on returning home, I would find myself getting way behind in all my other work (since TM is not, by any means, my whole job), as I tried to grind out a big meeting report from all those notes. This year I had a tiny computer with me — an NEC 8201 notebook computer, four pounds, battery powered, about the size of TM but 2" thick. This little machine contains 32K of memory, or about 20 pages of text, and will save a document onto a standard cassette tape player. This year, I had decided, I'm going to write the story while I'm there (or here). I that's what I did (am doing).



Ahh — that cool mountain air and bright sunshine!

Donald Rohe welcomed fourteen of us to the Third Annual Big Bear IAPPP Symposium at four, though, as he noted, the meeting had already been in session for a few hours as people arrived. He also asked for volunteers — KP duty — to set up the dining hall and wash out the pots and pans afterward. "Don't all rush," he said. "Everybody will have a chance." Next he announced that evening sessions with telescopes and photometers were planned to help those new to photometry get a little nitty-gritty hands-on finding stars and making readings with a photometer. The next morning, he said, we'd discuss how things had gone and learn from it. And yes, added Don, "let's keep the pace relaxed up here. Most of us lead a pretty hectic life where we've come from."

We began a round-table discussion about photometry. I include it because all telescope makers face that terrible question — to what use should I put my telescope?

"How bad a location can I have and still do useful work?"

There's a lot of work to be done on very bright stars, stars like Betelgeuse, more than enough to keep you busy. Even if you can only see objects fourth magnitude and brighter, there's

photometry for you to do. The big problem is finding comparison stars that are bright and stable.

"How do the solid state photometers compare with the PMT photometers? If I go out and buy one, how will it stack up?"

Solid state devices are easier to live with, hard to damage, but almost useless in the UV, useful on bright objects in the blue, and better in the red. With the PMT, you run into problems finding the object to center it in the diaphram before you run out of sensitivity.

"But aren't solid state photometers less sensitive?"

Louis Boyd, best known for his automatic photoelectric telescope, pointed out one of the facts of life of observational astronomy: "It's the brightest object of its class that's of greatest interest, not the dimmest. There's too much emphasis on working 11th magnitude objects. You'll find plenty to do above 8th magnitude, and the YBS catalog lists 9000 objects brighter than 6.6, and many of which need work. Don't put your telescope on a mountaintop — you'll do a lot more if you work from your backyard. If you put in two hours per night, you'll get a lot more done than you will on a mountain-top.

"Is the computer a necessary adjunct to PEP?" I asked.

The discussion that followed touched on the merits of learning the math, learning programming, and the sheer drudgery of reducing large amounts of data. The consensus, though, seems to be that one would not now contemplate serious photometry without the aid of a computer.

After supper that evening, we all helped set up three telescopes and photometers down by the chapel, to the north of the meeting hall while there was still light. As dusk came, we went back to the hall and I spoke my piece. "Photometry is tough to get into," I said, pointing out some of the informational barriers which bar many people from trying photometry, as well as the necessary involvements with math and electronics. But ready-made and high-quality photometers, telescopes with good drives, and microcomputers are all "enabling factors" which aid newcomers. In particular, I see computer programs for PEP data reduction becoming "the experts" that will help anybody convert raw readings into finished data.

After the talk, I hung around Don Rohe's telescope for the chance to examine and use the Optec SSP-3 photometer. It's an exceedingly well thought-out instrument, very easy to use. Using Don Rohe's 8" Meade 2080, mounted on a Byers 812, I took readings of several stars. I also tested the projected diaphragm to see how accurately it showed the edge of the sensor, which, I am pleased to report, it does very accurately.

Louis Boyd and Harry Miller discuss plans for a photometer head Harry plans to build. Rohe photo.

It was good to be outside at night under a clear, dark sky. Mars and Saturn blazed; the soft clouds of the Milky Way slowly lifted off the horizon. Scorpius rose, then Sagittarius, then Jupiter, bright as headlights. Sometime around midnight, however, the long day, the flight, the drive, all caught up with me, so I tromped back to the dorm and rolled into my sleeping bag.

High-Tech in the Mountains

Sunshine woke me at 6 am. I tried to roll over and go back to sleep, but it didn't work, so at 7 I gave up, got up, showered and went down to help set up the tables for breakfast. It was a fine morning: bright, sunny, dry, and 68 degrees. The symposium got underway around 9:30, when the morning's speakers drove in. "It's real foggy down there," said one as he got out of his car. I was glad to be in the mountains.

The first speaker was Steve Edberg. "The first thing I need to establish," he said, "is how to pronounce Halley. Halley rhymes with valley, even though Edmond probably called himself Hawley." He explained that the current emphasis was on getting accurate positions, important because the ESA Giotto probe is scheduled to pass within 600 km of the nucleus. The photometry network is active; there appear to be large variations in brightness, seen by CFH telescope, of perhaps 1 to 1.5 magnitudes, with an eight hour variation, but this is hard to reconcile with Steve Larson's rotation rate, based on 1910 photos, of 42 hours. Spectroscopy shows no detectable emission spectrum — it's shining by reflected sunlight. Steve concluded his whirlwind report with, "Oh yes, the Russian spacecraft will be launched in December. It's coming."

Steve also described the Halley trial run on Comet Crommelin, a more difficult observation than he had expected. "I learned you couldn't do a lot," he said. "The comet was so low it was all we could do to get enough star, comet, and star measures to get out good extinctions and differential magnitudes. It was hard to find the comet in the muck. It was very time consuming getting the extinctions, and we had very little time getting the data, but you can't get useful data without good extinctions on an object this low." Lumicon's Swan band filter, he reported, "seemed to increase the contrast of the object against the sky, and unless you have good setting circles, you're going to need a good star atlas, such as the AAVSO atlas, to locate a comet among the stars."

After a break, Jeff Hopkins spoke on data acquistion with his computers — a low speed (10 samples per second) system with a Commodore 64, and a faster (1000 samples per second) for S-100 bus systems. These are used with a pulse-counting system and increment counters built into the computer. Details on both systems are available from Jeff.

After a filling lunch of pizza, Alain Porter talked about the new CCD camera for the 200" Hale telescope, called the four-shooter. It is a marked improvement on the PFUEI, also a CCD

The Group Photo of the 1984 IAPPP Big Bear Symposium — a small group, but dedicated! Rohe photo.

camera, but reaches roughly 0.6 magnitudes fainter, to under 26th magnitude in a 5000-second exposure. Astonishingly, though, it can reach 21st magnitude in half a second. These highly-linear imagers have quantum efficiencies up to 30%. The four-shooter uses a four-sided reflective pyramid to split the image off to four 800 x 800 pixel TI chips, and was designed for ultra-deep cosmology. Alain's PhD thesis will involve surface photometry done with the new instruments; he told of the difficulties in reducing the mass of data from an 800 x 800 pixel array (erasure, flattening, cosmetology, analysis). At 0.33" per pixel, seeing limits the image quality, he said, and the total field is just under 9 arc-minutes square.

The pictures he showed were utterly magnificent — photographic in quality, with smooth tones and crisp images — the Crab, the Horsehead, NGC-3392, a cluster of galaxies at z = 0.5 rich enough that nearly every object in the frame was a galaxy. We are already seeing remarkable spin-offs from the Space Telescope, and it won't go into orbit for another two years.

Louis Boyd discussed the software side of microcomputer control of telescopes. His telescope, described in TM#22, was finished two years ago; getting the software right has filled the time since. "There's really only one advantage to an automated photometer," he said, "it can do an incredible amount of work. A human can turn out 6 to 8 complete data sets per night; this thing routinely does 75, and turned out 93 data sets on the best night so far." The data generally come out in the 0.02-magnitude standard deviation range.

When the Sun is 10° below the horizon, his telescope starts up, loads the complete list of stars to work on, and figures out which are within 45° of the zenith, then starts in on the westernmost objects. It steps the telescope over to where it expects the object, then searches for an object of the approximate correct count in a square spiral search pattern. For the first star of the night, the search takes about two minutes, but for later stars it rarely exceeds 10 or 25 seconds.

Each data group consists of the program star, a comparison star, and a navigation check star. The chances of the telescope's getting all three stars wrong is very small. After finding it, it then centers the star in the diaphragm, and then starts the UBV sequence. It does check, sky, comparison variable through three sets, then goes to the comparison. Each set of 33 readings takes about six minutes. The system can handle about 100 stars on its program; Louis currently has 73.

Jeff Hopkins gave an update on the eclipsing binary Epsilon Aurigae (HR1605), which has just recently emerged from eclipse, and on the IAPPP's photometric campaign. "Epsilon has been doing wild things," said Jeff, noting the mid-eclipse brightening, "and there was a very intersting pre-egress brightening in the UV". Pulsations of 100-day period complicate the light curve, as do flare-like variations on a time-scale of minutes. Ultraviolet variations of $\frac{1}{20}$th magnitude and a scale of three days may also exist. Follow-on observations for at least a year are planned to help disentangle these effects from the eclipse itself.

Dead-time and transformation coefficients are fundamental to accurate photometry. Deadtime errors result from the PM tube or the amplifiers counting two or more pulses as one. Louis explained an observational method of determining departures from linearity. Rick Wasson showed examples of transformation coefficient determination — making the data comparable to the definition of the original UBV system — "essentially just color correcting," he said. Hall and Genet's book explains how to do it.

After dinner and KP duty, we reassembled for The Group Photo. One of the local burros wandered by but did not join the picture. Next came drawings for door prizes — three in all, and all from Optec. Jeff Hopkins presented a plaque to Don Rohe for his efforts in running the symposium.

We saw slides of the Lines Observatory's 20" f/25 photometric telescope shown by Louis. "Put a good guidescope on — that'll save you from flipping the mirrors," said Boyd, whose own automatated telescope sprang from the challenge by Mrs. Lines to stop suggesting that they motorize their telescope, build one himself, and motorize it. Louis, of course, did just that. Jeff showed slides of his observatory — with C-64 and Zenith 100 computers and C-8 and Odyssey II telescopes.

Dave Rettig next showed his slides of his attic observatory. Two plastic domes slide aside. The telescope is an 8" f/4.5 RC reflector only 11" long, and a prize-winner at last year's RTMC.

During the afternoon clouds had been moving in slowly, and by evening they had not yet cleared away, so we watched a 20-minute video tape narrated by Pete Manly showing what video astronomy can do. Darrald Nye topped off the evening with the story of the 18-foot dome recently installed in his backyard.

The clouds had thinned and the sky was full of stars — Scorpius rising somewhat murkily in the east — but after cider and talk with the others in the dining hall, I curled up in my sleeping bag and went to sleep.

The RTMC Arrives

In those early mornings of the IAPPP, Camp Oakes was a wonderfully peaceful place. I pulled on a extra sweater and wandered around the grounds. The morning Sun was warm and golden, the air brisk, and the sky blue. They've had a very dry Spring this year, but everywhere I looked, small white flowers poked up from the ground. Then, lured by the thought and imagined smell of hot coffee, I walked down to the dining hall and helped set

the three tables our group required.

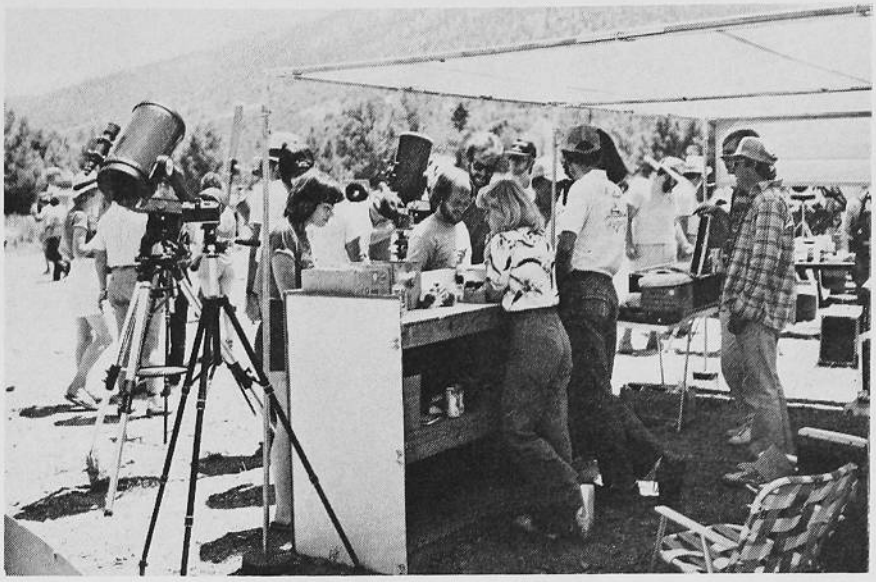
After breakfast, while waiting for the morning IAPPP to begin, a number of us got into a discussion of what could (or should) be done to garner more respect for amateur astronomers. "Professional astronomers just don't think we know what we're doing," seemed to be the common complaint. Jeff Hopkins thought that a new term, something to replace "amateur," would help; Louis Boyd felt that doing good work and publishing papers would bring greater recognition of the amateur's value. Steve Edberg maintained that neither was the right solution, but did suggest that more attention to news media would help amateurs and professionals both. The session was called before we determined the answer.

Rick Wasson began by discussing the data he had taken the night before. The clouds, though thin, had affected his measurements, but he "just kept slugging away" and got data with errors of about 0.02 magnitude — not as good as it would have been on a clear night, but still useful. The final presentation was Jeff Hopkins' paper on CompuServe. In an informal way, we agreed to keep in touch via EMAIL — with Jeff serving as a hub — and to see whether we could maintain a bulletin for IAPPP members in Public Access. Send your IAPPP EMAIL to Jeff; he will edit it and post it for us all.

We ended the Third Annual Big Bear IAPPP meeting with a round of applause for Don Rohe, and informally an hour later as we cleared the lunch tables for the final time. Already the noise, vehicular traffic, and dust were increasing.

By early afternoon, Lumicon, Celestron, and Dick Nelson already had tables of goodies set up. (Dick is not a company; just a very determined individual.) Several hundred people had arrived and Celestron, in particular, seemed to be doing a land-office business in ultra-cut-rate eyepieces, star diagonals, mirror blanks, refractors, and binoculars. I asked, and was told the stuff was customer returns — rather than refurbish it, they sell it off at cost.

Out in mid-field, I saw Art Leonard unloading his Yolo. Art is a talkative guy and full of ideas. He has, for example, come up with an improved Yolo which he will be writing up for TM. It promises to be a story worth waiting for. Art also showed me an extraordinarily well-baffled 50mm refractor with a wide-angle three-element Huygenian eyepiece he designed himself. He was involved in making apodizing screens many years back. But more about apodizing later.



Business was booming! Mary Williams and Ron Ezra wait on customers at their booth. Rohe photo.

I was talking to Steve Coe when another fellow walked over. His name tag read Tom Osypowski — a name that seemed familiar. "You're from Milwaukee," I said. He was, indeed. Tom did pioneering high-resolution astrophotography at the M.A.S. observatory several decades ago. His current telescope is a 16" mounted on an equatorial platform, with an auxiliary observing table. To my infinite joy, Tom designed his platform by combining ideas from two articles that appeared in TM#19 — Wally Pursell's platform concept and the mechanical wizardry of Tom Martinez' Poncet. Both these authors would have been pleased to see their ideas so ably adapted.

As I walked around the the field, I was struck by the number of the commercial displays and the quality of what was offered for sale. Looking over the Meade and Celestron booths, I saw little that was new to me, but just a little farther up the field was Parks' big RV. I went over to say "Hi" and ended up talking to Maurice Sweiss, the owner of Parks Instrument Company and Scope City. Sweiss is a charming man, a Jordanian who speaks a smooth European English. "I know the names of the stars," he said, laughing because they're in his native tongue. He is taking a new direction in marketing telescopes to the general public. Scope City, the retail part of the business, offers a large showroom, many brands, parts for making telescopes, books and magazines, lots of advice, classes, and support to the neophyte, as well as a full range of backup services — in short, everything. Parks, known best for its fiberglass tubes, is a more traditional telescope company; they are now developing a line of quality equatorial Newtonians, even selling machined castings.

In the evening after dinner, Ashley McDermott opened the 1984 Riverside Telescope Makers Conference and introduced the evening speaker, Jim Jacobson of Coulter Optical. Jim spoke on visual high fidelity astronomy. "The subject is kinda controversial," said Jim, "but there really is a paradox about the way we see the universe today. We use our instruments to look at the universe, but the way we look at the universe determines the way we look upon it."

Said Jim, "John Dobson told me that he thinks the best way to see the universe would be to lie on your back on a platform on top of a palm tree on an island in the middle of the Pacific." Viewing from a dark sky, the Earth out of sight, would allow us to gaze outward and see the thing for itself, undistorted. He continued, "Our aim in observing is eliminate the distortions, or at very least, to aim toward fewer distortions."

He then outlined what he means by distortion: 1) having too little light to fill the eye's pupil, which dims the view; 2) seeing the Airy disk which makes the stars appear spuriously large; and 3) viewing through telescopes with one eye only, which our eyes and brain are not designed to do.

In visual high fidelity, telescopic distortion disappears.

"We're interested in normal field brightness telescopes — those that have a 7mm exit pupil." He mentioned binoculars which, he said, "provide some of the best views we have." Jim described how as a boy he had visited an older cousin who was an amateur astronomer. What he remembers vividly is that man telling him, "always

There were lots of telescopes up on the parade ground — several of them larger refractors. Rohe photo.

try to view the universe with your two eyes."

Astrophotography is wonderful because it reveals things we wouldn't otherwise see at all, but photography introduces distortion because it cannot distinguish the range of lights and darks the eye can. Quoting from Phillip Morrison's essay in *The Physics Teacher*, Jim reminded us that a photograph shows only a 10 to 1 range of light, while a real galaxy varies in brilliance over a range of at least 10,000 to 1 between the starlike core and the outer parts of the arms.

"We would like a photograph that captures that range," he said, "but there is no valid reason we cannot reproduce celestial views by other means." Jim outlined a hypothetical box with beamsplitters, an optical device to combine several different exposures, thereby reproducing bright central regions as well as the fainter outlying parts, with fiber optics to mimic the brightest stars, all illuminated by sources recreating the spectral distribution of the light from the galaxy itself. "There's a challenge to technology here; I hope someone does it. For me, it's a fun thing to think about seeing the universe and being involving in bringing it to the public." Can you imagine finding such a box in a museum when you were ten years old, and looking in?

As darkness fell, I walked on back to the dorm and pulled on long underwear, a warm cotton sweater, windbreaker and anorak, stuffed a blank cassette in my tape recorder, and headed up to the telescope field. There seemed to be a lot of activity — red flashlights bobbed in the darkness, and the babble of voices blended in pleasant hubba-hubba.

Carrying the recorder and mike, one ear wired for monitoring sound, I stood in lines, listened, talked with people, and looked through telescopes. Already, on this first night, there were too many 16″ and 17.5″ scopes to keep track of, and they were all being used with 13mm Nagler eyepieces! Instruments in this size range, and with that eyepiece, certainly bring out the best in classics like NGC-4565, M-51, NGC-5128 (which I had not seen before), and M-103.

The largest telescope on the field, by far, was David Shipman's 29″ f/4.5 trailer-mounted reflector. Its tube — 3′ square and 10′ long — boggles the mind by its sheer bulk. I had passed it by several times when, passing again, I noticed only a dozen or so people standing in line — and the telescope was pointing at M-13, the object I most wanted to see in it. Mr. Shipman had been answering questions all afternoon, and was pretty tired, but he gamely told me, too, about the 18-point flotation system and double sling system for the mirror. Two slings are necessary because the telescope swings horizon to zenith to horizon again, unlike most Dobsonians, to insure that the telescope trailer never interferes with the observing ladder. Good thinking. For transport, Shipman secures the mirror with six Nylon-tipped bolts from the side. The whole scope weighs in at 1200 pounds, remarkably light for such a large instrument. The tube box sides are, incidentally, made of ⅛″ shower-board Masonite!

Because of the uneven ground, the ladder was rather tippy, so Shipman, I, and other would-be observers took turns holding the ladder. Just as my turn came, though, Shipman decided M-13 was getting too near the zenith, and he wanted to switch to M-57. I managed to convince him I could handle a big Dobsonian near the zenith, and before he changed his mind again, I climbed the ladder.

My first glimpse through the eyepiece — another 13mm Nagler — was stunning. The cluster was a blaze of stars. I removed my glasses and carefully centered it. The central mass filled about half the field; Scotty Houston's three-bladed "propeller" was almost lost in the glow. I found that although I could not achieve critically sharp focus, stars were reasonably small at 256x. I opened the other eye to compare M-13's brightness to that of the naked-eye sky — individual cluster stars appeared as bright as the stars in Scorpius; their combined glow, if M-13 shone magnified in night Earth's sky, would easily cast shadows.

Among new commercial instruments, one of the most interesting is the Tele-Vue Renaissance. Al Nagler had promised me a long look, and he certainly delivered. We tried, I think, every eyepiece he had, from the 40 to the 4.6mm. The only fly in the ointment was a ring of dew that formed inside the objective, as captured New Jersey air condensed in the 7500-foot chill of Big Bear. The brass tube is very handsome; stars' reflections glimmered on the tube. The impressive feature of this telescope is the always-crisp imagery across the entire field at the lowest as well as the highest powers. The four-element lens design allows flattening the field and correcting astigmatism and other off-axis aberrations which cannot be corrected in a doublet.

Another telescope well worth looking through was Roger Sander's lightweight 24″ reflector, written up in "Gleanings," and once again I happened by when the line looked particularly short. M-51 is one of those treacherous deep-sky objects that sometimes fail to look good when everything would make you think they should look great; this was not one of those times. It looked superb. I spent two solid minutes looking at it, as long as the next person in line would allow, amazed at just how much of the spiral arms, obscuring matter in the companion, and superimposed foreground stars I could see. The telescope itself was somewhat more limber than I prefer, but considering its length, and the relative ease in transporting it, this seems a fair trade-off.

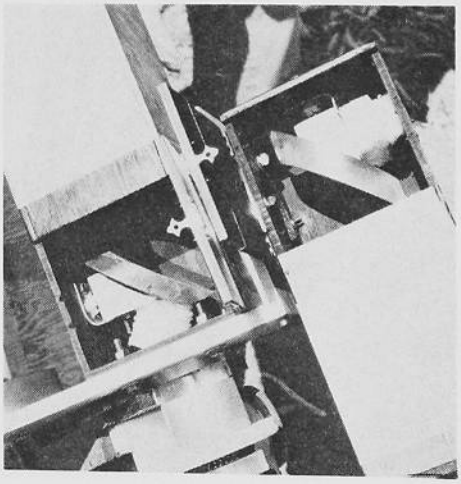
Two scopes which distinguished themselves solely on the basis of observing "feel" were Jeff Carmak's Dobsonian and Tom Osypowski's Pursell-platform mounted Dobsonian

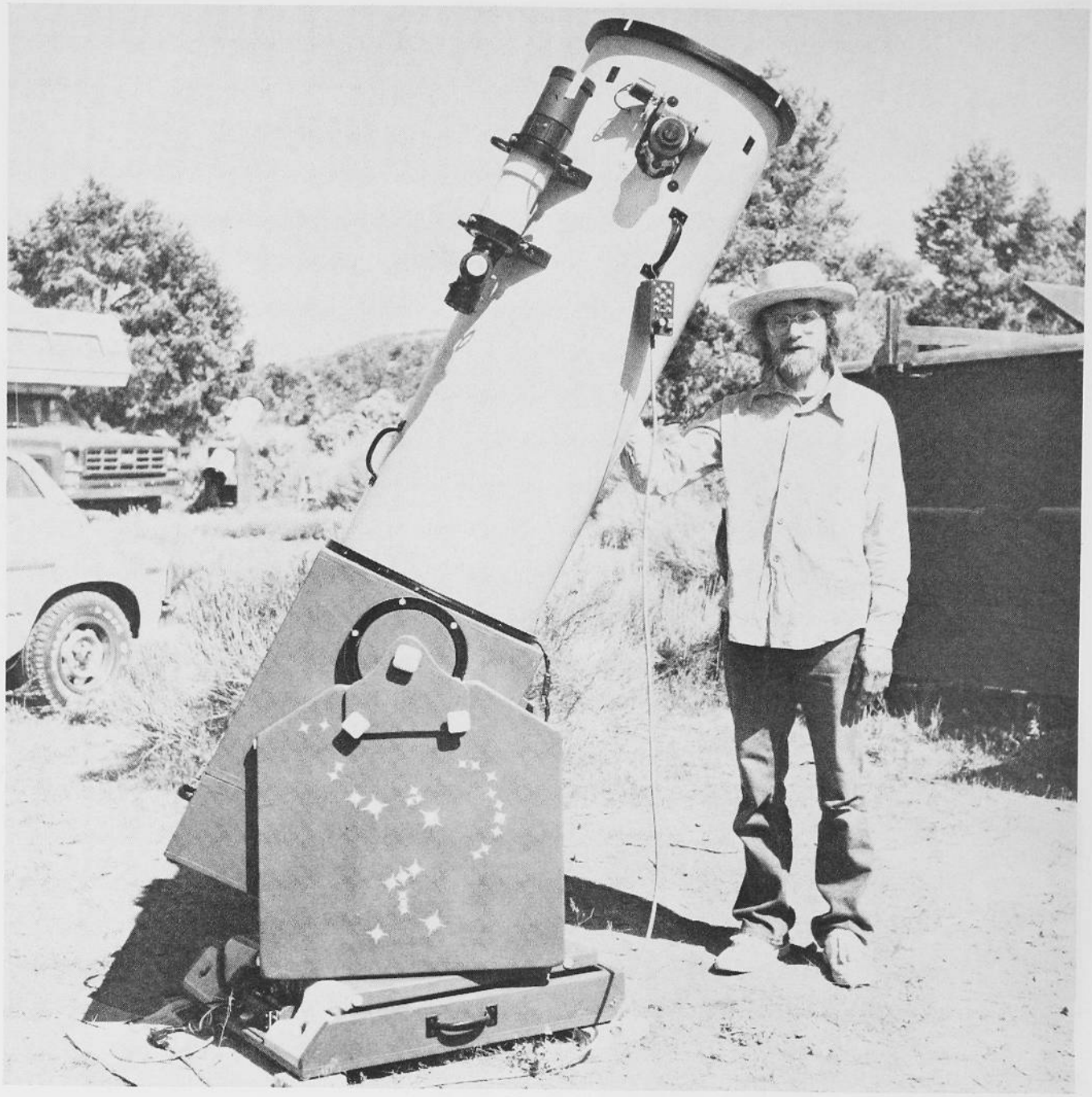
Cutting f/15 Down to Size . . .

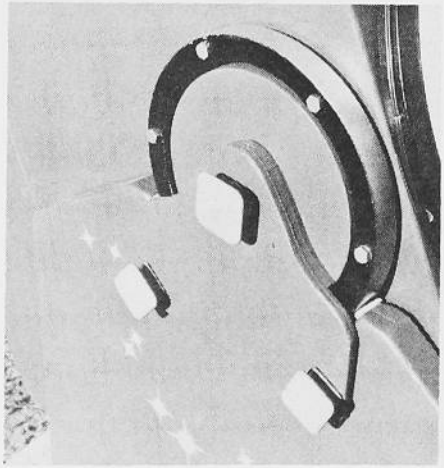
"I was just trying to bring the refractor down to a manageable size, instead of its being a headache," said Keith Lawson of his Paris Coude refractor. Keith considers the instrument a trial run before trying his hand at a much bigger aperture. This one, a 60mm f/15 and homemade except for the optics, allows the viewer to sit comfortably while observing.

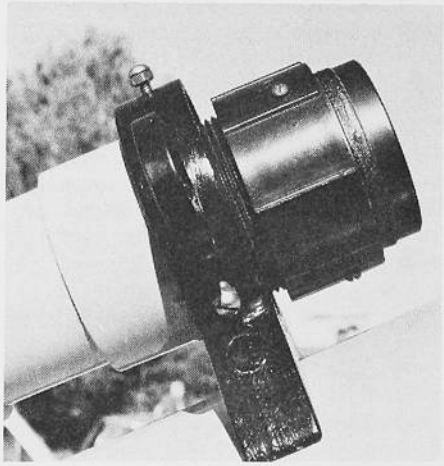
Light is reflected 90° from the first mirror (left) to the objective located in the declination bearing, then up the polar axis by the second diagonal. Both diagonals can be adjusted. A battery operated drive motor at the southern end of the polar axis turns a plexiglas worm; the Teflon drive gear "floats" on it.

Keith's work is distinguished by unusually clean lines and dramatic angularity — necessities of hollow box construction turned to the builder's advantage.









Big Aperture...

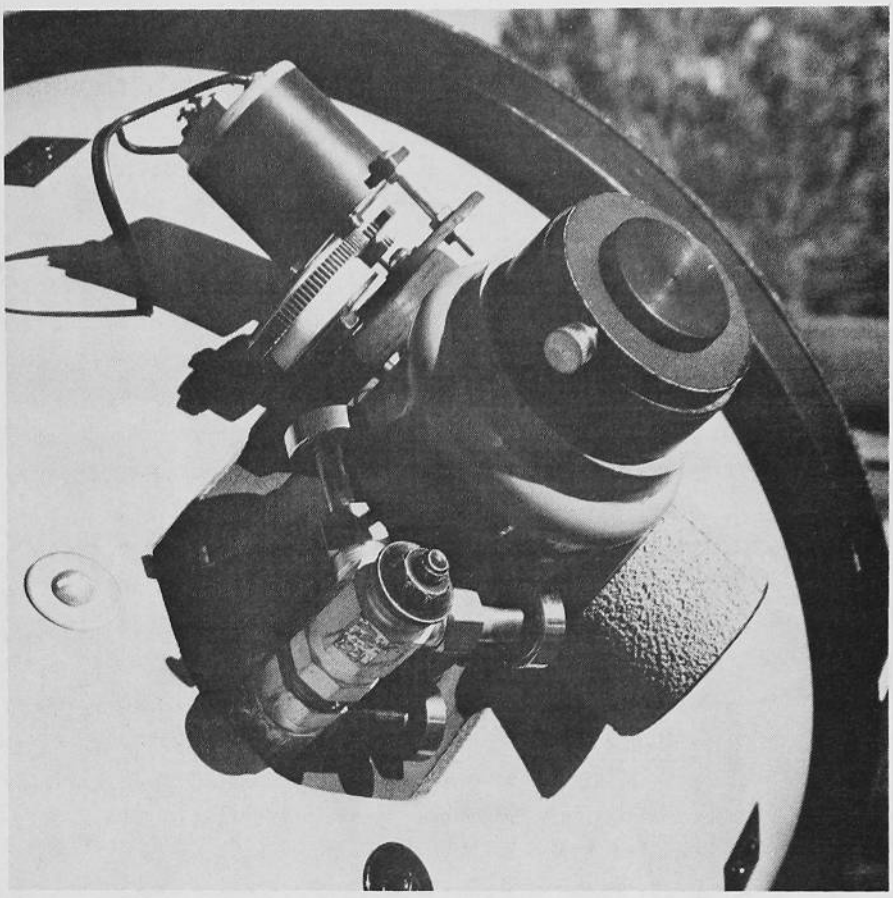
You had to look twice before noticing that Tom Osypowski's 16" f/5 Newtonian telescope is not your ordinary run-of-the-mill Dobsonian. Look closely: see the electric control paddle? Down at ground level, adding only 6" or so to the overall height of the telescope, is an equatorial drive system that means this Dobsonian tracks the stars, and tracks them smoothly and quietly. The system (lower right) is a modification of the Poncet platform described by Wally Pursell in TM#19. The bottom of the upper plate is a section of

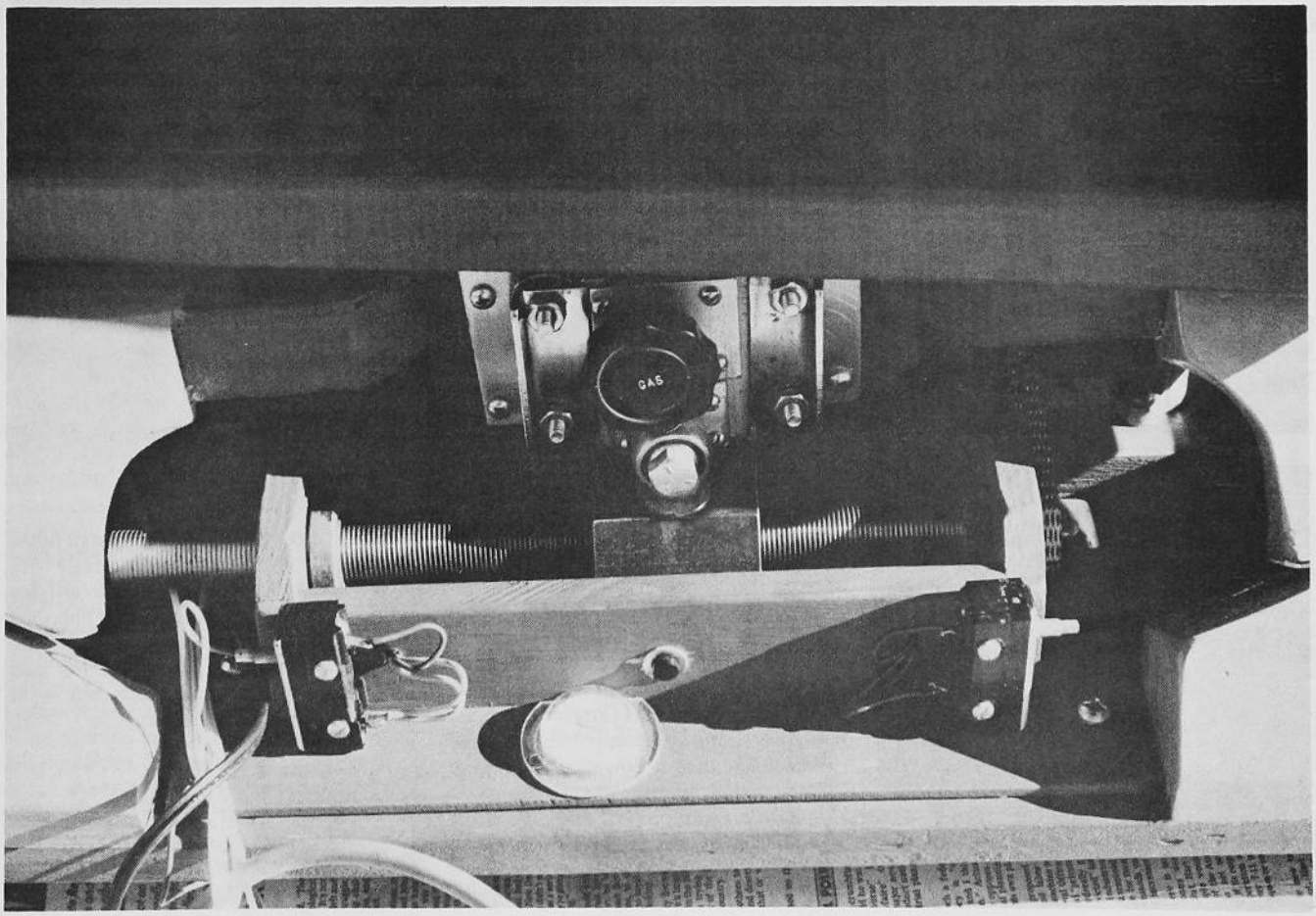
...plus Tracking

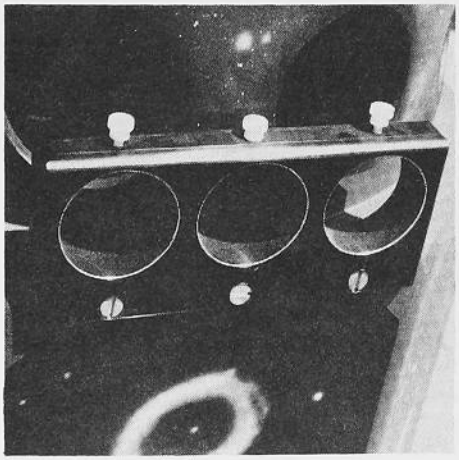
a large drive roller; it rolls on recessed ball bearings in the lower section. A heavy lead screw tracks for roughly one hour; the drive mechanism is based on Tom Martinez's Poncet platform, also described in TM#19.

For clamping the altitude axis during long observing sessions, Tom added a clutch to the side bearing. The telescope has a variety of other particularly "friendly" features. The focuser is a motor-driven version of the Crayford focuser (right), and permits rapid insertion of oversize eyepieces mounted in an ABS tube. The finder is home-built and also employs ABS plumbing components for focusing (lower left).

Do you recognize the constellation on the side board? Scorpius is on the other side. Do you recognize the stars? For those who do not, they're Edmund's glow-in-the-dark ones. I remember them well because those same stars shone from the ceiling of my room when I was a kid.







... Fine-tuned Smoothness plus Stability

It isn't often that someone reconstructs a commercial scope so thoroughly it's unrecognizable, but Jeff Carmak has. His 17.5" f/4.5 reflector started out as an Odyssey-2! What distinguishes this telescope, though, is the way it feels — rock solid and silky smooth. Jeff has completely rebuilt it, and his friend Garret Moore has rendered deep-sky objects on the tube exterior. The tube is now also ventilated.

During the day or when he wants to eliminate air motion, Jeff stretches a big cylinder of heavy-weight double-knit fabric over the tube. Also notable are machined 1¼" and 2" eyepiece racks, complete with nylon clamping screws, counterweights attached by Velco, dovetail slide mounted finders and auxiliary scopes, and Ensolite foam mounted primary mirror. Jeff also refigured the mirror — in its cell — to eliminate residual stresses.

which I had seen in that afternoon. Both instruments are particularly (in current jargon) user-friendly. Osypowski's tracks like an equatorial but offers the horizontal eyepiece and ease-of-use of a Dobsonian. Carmak's is fine-tuned for performance, possibly the best Dobsonian I've ever used, so satisfyingly stable and exceedingly smooth you forget it's a telescope you're looking through. Jeff has been the high-tech route and has returned to functional simplicity.

It was late. Though Scorpius stood on his tail and the rich fields of Sagittarius were just getting high enough to view, exhaustion that even hot tea and the pleasant fire in the dining hall fireplace could not quell overtook me — and so to bed.

RTMC's Big Day

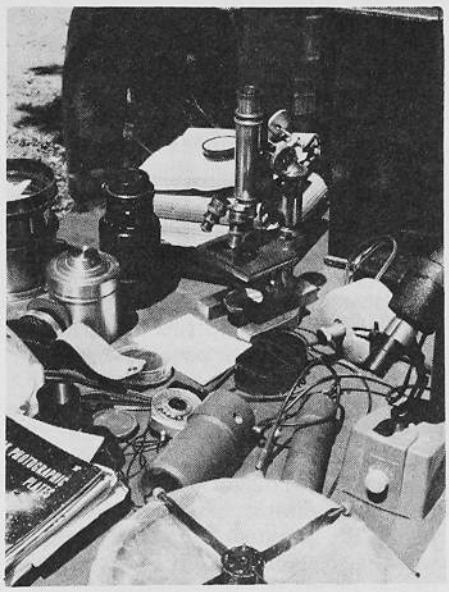
"WELCOME TO THE RIVERSIDE TELESCOPE MAKERS CONFERENCE!" proclaimed Ashley McDermott, opening this, the sixteenth. "I want to call your attention to a number of things," telling people how to register a telescope, where to find snack food, when the Swap Meet will be held, and the day's speakers. "We'll have star parties all tomorrow night, weather permitting," he added, stating the all-too-obvious.

Ashley called on Steve Edberg to welcome us on behalf of the WAA: "I'd just like to say 'Welcome' and invite you all to come to the ASP-AANC-WAA conference." Tom King, vice president of the Riverside society, warned us to stay away from the confidence course down by the lake — too dangerous. Ashley reiterated the importance of sticking to the camp rules: NO open fires and NO all-terrain vehicles.

Dire warnings completed, Ashley introduced the first speaker of the morning, Louis Boyd, to describe his automated photometric telescope. Louis described his telescope in considerably simpler terms than he had for the IAPPP, but in concluding, he mentioned something really interesting: "Although I had undertaken the project more as a challenge in electronics, I've now gotten hooked on astronomy."

Norm Sperling was the morning's next speaker. His tee-shirt announced, "Everything in the Universe is in Oakland," and the title listed in the program was "The Four Great Questions of Astronomy." Although I wanted to go on up to the field and look at telescopes, I must admit that I stayed out of sheer curiosity. Norm took a fresh approach — rather than treating the history of astronomy as a series of events, he described the whole of astronomy as the pursuit of answers to four big questions. Question 1: How does the Earth move? Norm had fine visuals. He showed armillaries, celestial spheres, astrolabes planespheres, and astronomical clocks. Question 2: How does the sky move? This is the question Copernicus was trying to answer. Question 3: What is the nature of objects in space? Astrophysics originally meant this literally; spectoscopy revolutionized it. Question 4: How has the universe and the objects in it evolved? "We've always had notions," observed Norm, "but now some answers have some substance." He also added a Question 5, the one begging to be asked, and perhaps the next big question: Why?

The Swap Meet was an event all by itself this year. I had enough cash to buy pretty much anything I could carry home on an airplane (this is a major



limitation!), but nothing big struck my fancy. Of course, some of that comes from having just finished a book about building telescopes, and building five telescopes in the process; I've got just about everything I need. Still, I could have been tempted by a li'l ol' lens for just the right price, maybe, or a bargain eyepiece. I did buy some nice Ronchi-grating "eyepieces" from Dick Nelson, though. Rick Shaffer had less restraint: he bought into a very big project. Two days later I saw it in his van — a square of glass big enough to cut a disk 31" in diameter from. I didn't ask how much he paid; don't tempt me!

The gem I did find came from one of the commercial dealers. Optec had a stack of 1¼" and 2" Cheshire alignment "eyepieces," which they were selling for $12 and $15, respectively. These are not your ordinary alignment gadget — they feature first-class workmanship throughout, anodized aluminum with a beautifully polished 45-degree reflecting screen. I bought one of each and a spare 1¼"-er for Dave Eicher. I guess I got the last one in the 1¼" size, but Optec still has them in the 2" size. They've also got meteorites.

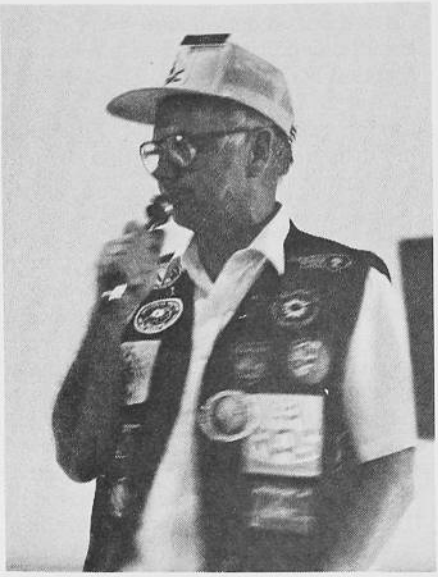
The Sun was very strong; I put on a white long-sleeved shirt to protect my still-tender skin from it. I wanted to tan, not burn. Alain Porter, who had been at the IAPPP meeting, had already fried himself thoroughly, and was wearing a towel over his head. Up on the field I looked at telescopes, talked to people, took copious notes, talked to people, looked at telescopes, and finally started to fry despite my precautions. I spent the late afternoon sitting comfortably under a big pine tree pounding the keys on my computer, writing what you've been reading.

At 7 p.m., we all trundled over to the dining hall for the Saturday night doorprize drawing. Tickets were handed out at the door — so each ticket drawn would correspond to someone present. The hall was chockfull: people crouched on the floor in front, stood in the aisles around the back and sides, and, of course, filled every seat. Things finally got going when Cliff Holmes, who'd been at work and arrived late, took the mike, and called the evening session to order: "Yodellay-hay-ho! Well, we've got some great gals and guys here, and I know what you're all waiting for!" (And I'm sitting here typing it all into my little computer, trying to learn whether this is the way of the future.)

The first door prize, a Halley Watch tee shirt, was won by Camp Oakes' hard-working director. It seemed appropriate. The second was a weather chart, then a warm hat from Mary Firth (I bought one of her caps the year it was cold), then a 2.4" guidescope from Parks, won by Scott from Camp Oakes. Next came a filter from Lumicon. "It's got H-beta and all that," said Cliff. A 2" barrel 50mm eyepiece from Parks was next. As Maurice Sweiss read the number, the winner let out a surprised, "Ah-haha," as he realized he held the winning ticket. Everything in the Universe donated an analemma chart. Another Parks eyepiece drew a little ripple of oohs from the crowd — this one a 60mm in a 2" barrel. There must have been a lot of people with long-focus telescopes hoping to win it.

The two biggest prizes came last.

"Kevin, Kevin, where are you?" called Cliff, as Celestron's Kevin Ritschel came in the rear door to draw the stub for a Super C-8 with Starbright coatings, their trade name for anti- and



Cliff Holmes

high-reflectance coatings. The second big prize was a 2080; while Meade's Pam Diebel drew the winning ticket, John Diebel grinned and quipped, "Yes, I'm afraid the winner should put this on his 1984 income tax!"

After the drawings, things quieted a bit. Some people left and others tried to squeeze in and find a seat somewhere. Ashley introduced this year's featured speaker: "Ben Mayer has done marvelous things; he's even gotten an asteroid named after himself."

Ben began, "It is 12 years since I first aimed a telescope away from a girl's navel," he began, "and perhaps became the first Peeping Tom to graduate to amateur astronomer." Ben grew into astronomy in a big way, "As I learned more and more," he said, "I learned how much there is to know and how little I knew. At that point I decided to write a book." *Starwatch* is that book; it teaches anyone how to find the stars and constellations. Ben's next will be *Astronomy: Odd and Even*, the odd chapters written by Ben and even chapters by Bill Liller. His third book will be on finding Comet Halley using the Starframe concept. "It is important to know where one is," he says of *Starwatch*, "and a thrill to help others find where they are." Capturing the spirit of a Ben Mayer speech is impossible, because the message is not in the words. The enthusiasm and energy convey something words cannot.

I talked to Ben later that evening, both of us perched on the rear bumper of his RV, looking into the darkness across the crowd and the lines of people waiting for a glimpse through a telescope, and he said, "Richard, do you realize that it has been twelve years. Twelve years!" Twelve years since discovering the stars by gazing at navels. Each of us reaches in his own way; there wasn't much I could say. Little things, chance or happenstance, change our lives, and it is both frightening and exciting. I discovered the stars in sixth grade, shortly after I got my first pair of glasses. My own life, I realize, changed when I took a job with a small publishing company — and here I am watching the glittering stars of Scorpius rise over a peak in the San Bernardino mountains, in the peaceful company of a thousand like souls, who are also watching the stars rise.

While I was talking to Ben and watching the stars, my camera was watching them, too. Several months ago, Kodak had sent several rolls of the new P800/1600 slide film for testing. This stuff can be pushed to 3200 ASA, so after preliminary testing under Wisconsin's cloudy spring skies, I'd brought a roll to try some hard-to-get starparty-by-starlight photos. I borrowed a tripod from the Celestron people (thanks, guys!) and for the rest of the night set my camera in various spots with the shutter open for times ranging from 10 seconds to 30 minutes.

Since the longest lines tended to form at the biggest telescopes, I went for the smaller instruments. I spent a good half-hour with a Questar 7″, long enough to get down pat what each of the little knobs on the back does. The instrument is seductive — flip, flip, flip, from finder to main scope to high power — but like every other telescope, it was limited by the seeing. Immediately after viewing with the 7″ Maksutov-Cassegrain, I stood in line for Siegfried Jachmann's 9″ f/14.6 Clark refractor. Given the poor seeing conditions at Riverside that night, it's impossible to say which would be better on a really steady night, though I think the refractor would have shown a slight edge in resolution though handicapped by secondary spectrum.

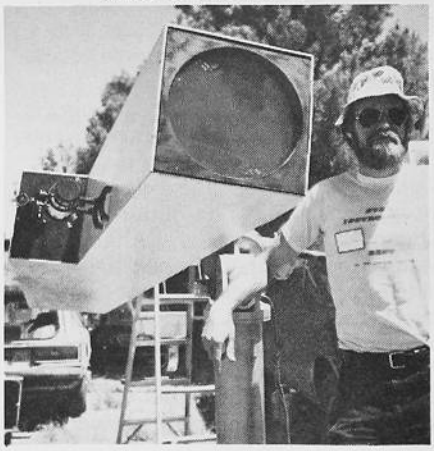
Although I did not get to view with the others, Kevin Medlock's 6″, an 8″, and Paul Jones' 10″ f/15 refractors were also set up. Paul's doublet was computer-optimized by Mike Simmons, of Simak fame, and has an 0.4-inch airspace between the elements. Paul has mounted his prototype in a box made of ¼″ plywood, and uses a rather big flat to fold the light path. "The big flat helps balance the scope," he said, "but I'm going to replace it with a 4″ flat. That's all it needs." On the professional side, Paul is doing some impressively big optics: two 40″ solid mirrors and two 48″ cellular blanks, if I have been able to read my notes correctly!

One of the things from that night which I want to mention is Steve Coe's observing steps. After you've stood on a dozen shaky ladders, you can appreciate a solid footing. I couldn't see it in the dark that night, but I knew Steve had some very solid steps for his telescope, with a solid handrail at the top, which I found very reassuring. The next day he showed me what I'd been standing on: stairs made for a house trailer! They're roughly 30″ wide and three steps high; he had added two angle irons supporting a rail. He sometimes hooks a shelf over the rail for his deep-sky object drawing supplies and finding charts.

I stayed up 'til two that night. As it got later, the lines diminished and it was easy to get a look through the various telescopes. I swept up several dozen Virgo galaxies in fifteen minutes with one telescope, then joined some poeple looking at planetaries. But as I grew tired, I found myself standing and staring at the Milky Way naked eye, admiring the the manic brilliance of the stars against the woolly starclouds and twining dark nebulae. When everything is said and done, and you've fully satisfied the urge to look through big and powerful telescopes and seen the galaxies and clusters and nebulae, the naked-eye view may still be the best view there is.

Siegfried Jachmann's 9″ Clark

Paul Jones and his 10″



Peaceful Sunday

It is always a shock, waking in the morning and looking out the window to see the opaque blue of the sky where only hours before the stars of Sagittarius and the fringes of the nucleus of the Galaxy had gleamed. My arms and neck were sunburned, but not badly, so I celebrated by putting on my "I survived Riverside 1980" tee-shirt. Having decided to attend the morning paper sessions, I wanted to be comfortable in the rather warm auditorium.

John Mood presented a talk on atmospheric optics based on an ASTRONOMY article he had written several years ago. "Watch the skies," his voice made mechanical by the way he held the microphone, in imitation of the sound track of *Close Encounters*. John is a vivid presenter, and described all the variety of halos, rainbows, sundogs, and lights we see in the sky.

David Levy spoke on Bart Bok, encounters with and anecdotes. David interviewed this great astronomer extensively during the last several years, and is now writing his biography.

Next, Steve Edberg spoke on what apodizing is and isn't. For those who've never heard of it, apodizing means tapering the amount of light reaching some zones on an optical system in order to improve some specific performance characteristic. Amateur astronomers have typically used multiple layers of window screening to taper the aperture. It seems to me that a thin Mylar sheet such as Tuthill's Solar Skreen, but not aluminized, could be spray painted in an effective Gaussian taper, and would, in addition, reduce air currents in the tube.

At the risk of over-simplifying, Steve had calculated the point spread function for an aperture with several different apodizing functions, and concluded that apodizing typically broadens the Airy disk but reduces the intensity of the diffraction rings. Steve confirmed this by examining telescopic images. He maintains, however, that apodizing should not improve telescopic seeing because seeing is external to the telescope. In tests on stars, Steve noticed that a neutral density filter produces much the same effect as an apodizing screen, proposing that it is the reduction in image glare that produces the improvment in image quality. His talk will appear as an article in the next TM.

Apodizing came up in TM#16 and has been batted about ever since. The real question for me is: How does apodizing work? I had already talked to Jim Van Nuland and Art Leonard, explaining that we're not trying to show that they're wrong, but trying to gain understanding, and think I got through to them. We agreed to try some screens that night.

In the early afternoon I sat under my pine tree again, transcribing my notes and writing about the morning on the NEC computer. I spent the late afternoon photographing the more interesting telescopes I'd looked through the night before and talking to their owners. To my surprise, a lot of people had already left; only about half the telescopes remained by dinnertime.

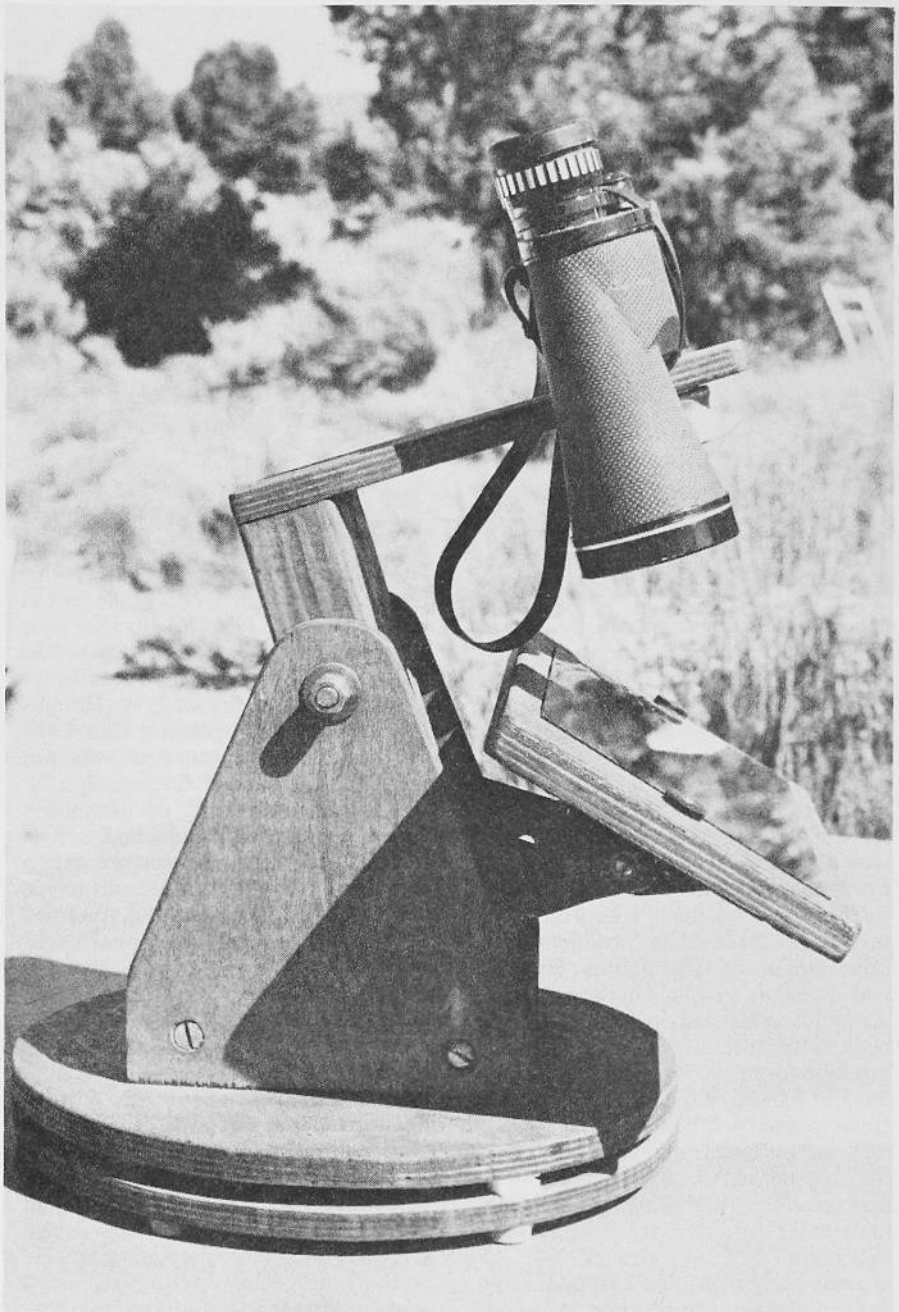
After dinner we reassembled for the awards and door prizes. I squeezed my way to the front, ending up sitting on the floor where I could not only see the projection screen, but could also scribble the names of winners and their prizes frantically in my little notebook (the floor is no place for typing on a computer).

As has become the tradition at RTMC, the awards committee announced the winners: the Junior Division Award, Doug Thomas for Best First Telescope; Daune Neuhaus for Excellent Execution of a Folded Refractor; Sue Pasco, Exceptional Execution of a Coude Refractor; an honorable mention to Jeff Kysor for his Star Finder; Kevin Medlock, Excellent Design of a Drive for his 6" refractor; Rick Swenson for his telescope with huge setting circles; Gordon McDonald for his Fine Wood Telescope; Dave Kenyon, Electronic Drive Controller; Keith Lawson, Unique Execution in Mechanics and Optics; Bob Pfaff, Mercury Floatation Mirror Edge Support; Dave Retisevich for Computer Integration in a Telescope Design; Timothy Barker for Handtool Craftsmanship; Tom Osypowski, Fine Equatorial Platform; and Mike Hill for his sculpted Unique Wood Design. John Day received the Warren Estes Award for use of simple materials; as he picked up the award he said, "the focuser tube is a sawed-off deodorant can." The whole telescope cost him $35.

The winner of the Cliff W. Holmes Award, presented by Richard Porrimba of Astronomy for America, was Jim Jacobson, the head of Coulter Optical. The Holmes Award is presented annually to the individual who has done the most for amateur telescope making, and Jim, through Coulter, deserves credit for making the "Big Aperture Revolution" possible for thousands of us. Jim was not there to receive the award: he had left earlier in the day, exausted. With all earnestness, I hope that he will take life a little easier, for his own sake as well as ours.

After the meeting, I headed toward my dorm to put away my cameras and pull on some warmer clothing; on the way I bumped into Clifford Livermore (you may remember his Letter in TM#11), and ended up talking to him for what must have been an hour. He is an "outrageous" individual with a sense of humor and of himself that I've seldom seen matched — you have to meet him to know what I mean. I finally did get back, pulled on long underwear and a heavy jacket, hung the camera with 3200 ASA film around my neck, and tromped off to try apodizing screens on Jeff Carmac's 17.5" Dobsonian and Art Leonard's Yolo. As it worked out, I never got over to the Yolo, but instead spent over an hour carefully comparing the performance of a 6" unobstructed aperture and a mesh Jeff had optimized empirically.

We started with Saturn, then tried Mars, Alpha Herculis, Vega, and Epsilon Lyrae. I really hogged the eyepiece, and was grateful for the indulgence of the others who let me. Jeff's scope is an excellent test-bed. It has excellent optics, is very stable,



Tom Osypowski's Dobsonian binocular mount proved to be smooth-moving and easy to use.

moves smoothly — in fact, it wins my personal "Smoothest Scope That I Observed With At Riverside This Year" award.

The results? Saturn definitely looked better with the screen in place. More detail was visible on the ball of the planet, and during the 20 minutes or so that I spent on Saturn, Cassini's division was visible a higher fraction of the time, and with equal or better contrast. The screen dims the planet's image, which surely accounts for some of the difference, but we didn't have a "neutral density" screen on hand to test the effect of the dimming effect by itself. One effect worth noting is that the edge of the planet seemed stabler and seemed to suffer seeing "blow-ups" less frequently than the unobstructed aperture. Mars was all but devoid of detail without the screen, but showed some low contrast markings with it. Again, I suspect dimming plays some role, but is not the whole explanation. Incidentally, Edmund Scientific sold apodizing masks as "Metzger Glare Reduction Filters" for many years. I don't know who Metzger was, but he clearly favored the glare reduction theory.

We tried double stars less in the spirit of investigation than from simple curiosity. Alpha Herculis is a pretty double, and the effect of the mask was to reduce parasitic light between the stellar images. Epsilon Lyrae, which Clifford suggested, was beautiful with its twin diffraction patterns.

Telling observations were those of Vega, extra- and intra-focally. The unobstructed 6″ aperture yielded the classic diffraction patterns with a bright ring and lower contrast internal diffraction. The out-of-focus apodized aperture showed no rings at all, but a feathered, rather than bright, edge. Rings did not seem to form in the apodized aperture either in or out of focus.

The in-focus image showed no central Airy disk in either case, but was instead broken into a pattern of rapidly-moving speckles by poor seeing. With the unobstructed aperture, the speckles were more numerous and smaller than those with the mask. The overall diameter of the blur circle appeared to be just about the same in both cases. I switched between the screen and the unobstructed aperture at least a dozen times with Vega to eliminate first impressions and possible bias on the parts of the observer.

Jeff's screen is made of four layers of blackened ⅛″ hardware cloth. Their diameters step down in increments of ¾″, with a central opening of 3″, if I understood him correctly. I think that an apodizing screen would be a useful accessory for every observing box, but I am still uncomfortable that no one has explained their operation in a satisfying way.

It had become late enough that Sagittarius stood well above the horizon and the band of the Milky Way stretched in a broad arc across the eastern sky. I walked over to the Yolo and found it shut down for the night, a chance I regret having missed. Still energetic, I continued my picture taking with frame after frame of Kodak's new 3200 ASA film, hoping to capture that magic on film.

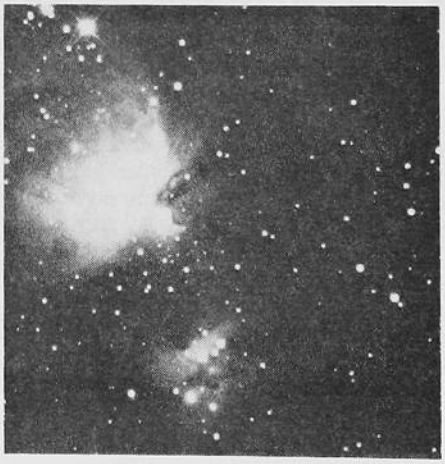
The final hour of that night I spent observing with Dana Patchek's and his 19″ telescope. Dana knows where to find some of E.E.Barnard's dark nebulae, and was showing Rose Mengoza, a most delightful member of the Riverside club, B-objects one after another. She named B-92 the Dragonfly Nebula, a name that deserves to stick.

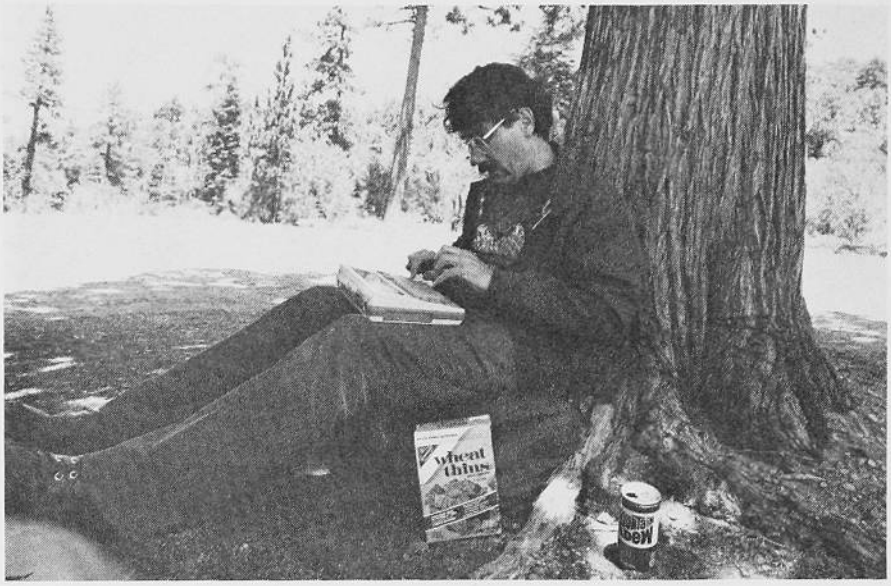
I had never seen any of these before though I had photographed quite a few, so was delighted to find that from a dark sky with a large telescope they are actually quite easy to see.

But all good things must come to end. After shooting the last frame of the superfast film, locating Pluto with Dana's scope, and taking a final look at the bright swirls of the Lagoon Nebula, I plodded back to the dorm on tired feet and crawled into my sleeping bag.

Bowling for Photos...

Dick Housekeeper pioneered the photo-Poncet; now he's taken on the bowling ball! The polar axis is a 2x4, swinging on door hinges top and bottom, and driven in RA by a long tangent-arm. The threaded rod and the motor swivel in a spherical bearing so that the nut is always aligned. The bowling ball rests on Teflon pads in a wooden tripod. The Orion Nebula shot was made on VR-1000 film with the 6" f/4 photo telescope.





Transition

I slept late on Monday, waking just in time for breakfast. Even as I walked toward the dining hall, cars, truckers, and motorhomes were rolling out. The sixteenth Riverside conference was drawing to an end. After eating, I strolled around the nearly-empty field one last time, yakked with Norm Sperling for a while, admired the huge chunk of glass Rick Shaffer bought at the swap meet, then went back to the dorm, showered, packed, loaded the car, and just before noon, bid Camp Oakes adieu.

Now it was time to get to work! I drove to the pull out on Onyx Summit, elevation 8,200 feet, parked the car in the shade of a big tree, then settled down for a lunch of crackers and Mountain Dew — and a couple hours of serious writing. This is where my little portable NEC computer is priceless; words come easily in such a beautiful setting.

Around three I drove down to Running Springs, about halfway down the mountain, checked into a pleasant little motel there, and took a much needed nap. After dinner I settled down to continue writing and revising this article, saved completed text onto a cassette tape, then erased it from the machine to free more RAM. The machine's 32 kilobytes is equivalent to 20 standard double-spaced typed pages, and takes about five minutes to save on tape.

The next morning I drove the rest of the the way down the mountain, back into the smog and oppressive heat, down I-10 to Ontario, then flew to Dallas. While waiting for the plane to Midland/Odessa, who should walk over but Jack Newton, noted astrophotographer. Jack had encountered Norm Sperling and David Levy, on their way to Atlanta for the eclipse, only a few minutes before. Then, as we boarded the plane, Alan French, whom I had met the year before at Stellafane, spotted us and came over to say hello.

In the airport after the flight, we met yet another Texas Star Party goer whose baggage had accidentally been tagged for Sacramento; he was hanging around the airport until 9:30 that evening when his bags were scheduled to arrive. Jack and Alan both drove to the Prude Ranch that night, but I stayed in Midland for another evening of writing.

Texas

Oil wells dotted the treeless landscape of the Permian Basin as I left Midland/Odessa behind and headed west on I-20. The morning was cool and crisp, with a strong wind blowing. It is not hard to imagine any place so flat as an ancient sea bottom accumulating layers of ooze that would, in our millennium, become oil.

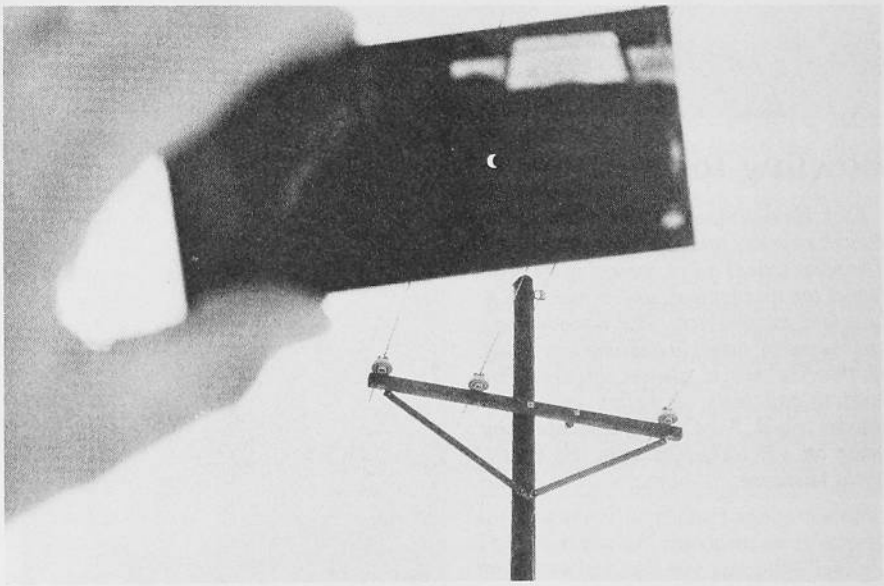
A little after 9:30, looking through a dense welder's glass, I noticed the first lunar nibble in the solar disk. Other drivers probably wondered what I was doing swerving around the road. As the eclipse deepened, the landscape seemed to sharpen. Although it did not seem any darker, I was able to take off my sunglasses by 10.

I stopped several times to take eclipse photos and get a closer look at one of the ubiquitous "all-whale" pumps. I was squinting into the viewfinder with the camera pointed into the sky when suddenly a half-ton pickup skidded to a halt on the shoulder of the road. The driver hopped out, brandishing a camera with a filter-covered telephoto lens. "Gettin' good pictures?" he asked, handing me *his* camera for a look. "Sure," I said, too surprised to be coherent. He held the camera up again, shot a few frames, then hopped back into his truck. "Well, I gotta go. Got a well to take care of," and zoomed off.

A few miles farther down the Interstate, I saw another pickup pulled over on the shoulder, and a man wearing a welder's mask standing beside it — looking up!

Mid-eclipse, for me, occurred in Pecos, where I turned south onto 17, and the character of the land changes. Cotton and cattle grow here, and the Davis mountains loomed ahead in the atmospheric haze. For most of the sixty miles I drove on it, I was the only car in sight, and the pavement is straight, level, and reasonably smooth. 17 is a good road for going fast. At Balmorea, rocks suddenly thrust out of the ground, water becomes abundant enough for trees to grow, and 17 begins its rise into the mountains. The sky grew bluer.

I reached Fort Davis at noon, driving

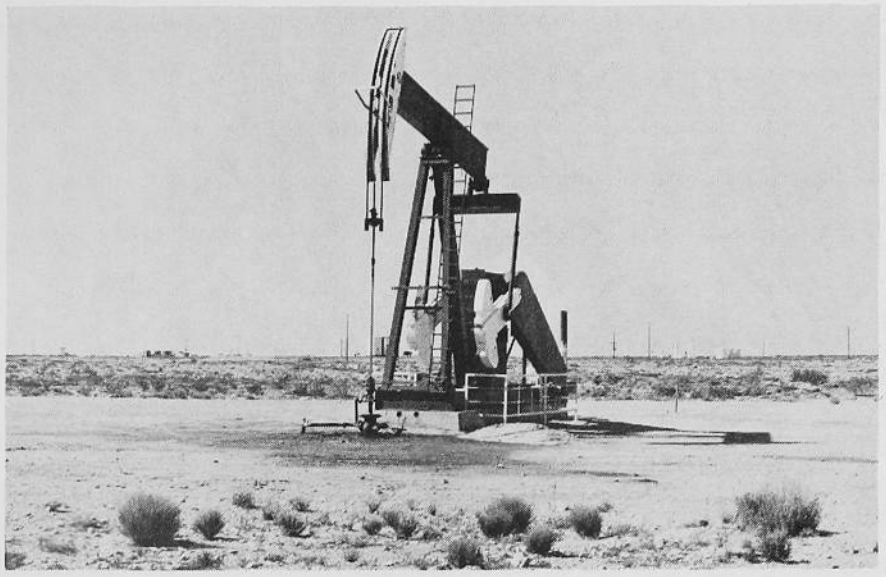


the last miles up a winding canyon, and checked in at the main gate of the Prude Ranch. Things seemed to be slightly confused as they didn't have my registration forms, but the woman there called one of the organizing committee on the walkie-talkie. He came out, and I was duly tagged, certified, and allowed in.

We had arrived right at the end of lunch-hour, so after a quick lunch, I met George Ellis, who showed me my bunk in "Walnut" dormitory. Jack Newton had the adjacent bunk — I recognized his luggage from the boxes of deep-sky photos spread out on a new sleeping bag. I hauled my stuff in, put on some fresh clothes, and headed toward the gym. My first talk, for the IAPPP session, was scheduled for 3:20. After a quick review of my notes, I walked in and delivered the talk to the small group in the auditorium. I like to hear all the papers in session so as to "get into the flow," but this time it wasn't possible.

The rest of the afternoon was a crazy whirlwind. Ed Boutwell, his infectious enthusiasm turned on full, asked if I wanted to go up to McDonald Observatory. I said, "Sure," so off we went with Jack Newton and Joe Liddell, the now-retired head of the McDonald machine shop. Between Ed and Joe, Jack and I got a great tour, since we all seemed to be feeling exuberant and more or less nutty. Joe, of course, knows everybody there, Ed has charmed his way into the staff's good graces, and McDonald is, in any case, the friendliest of the major observatories in the US.

While we there, the 107″ telescope was being fitted with a new secondary flip cage. The telescope was swung horizontal under the polar axis. Looking down the tube, I could see the seven

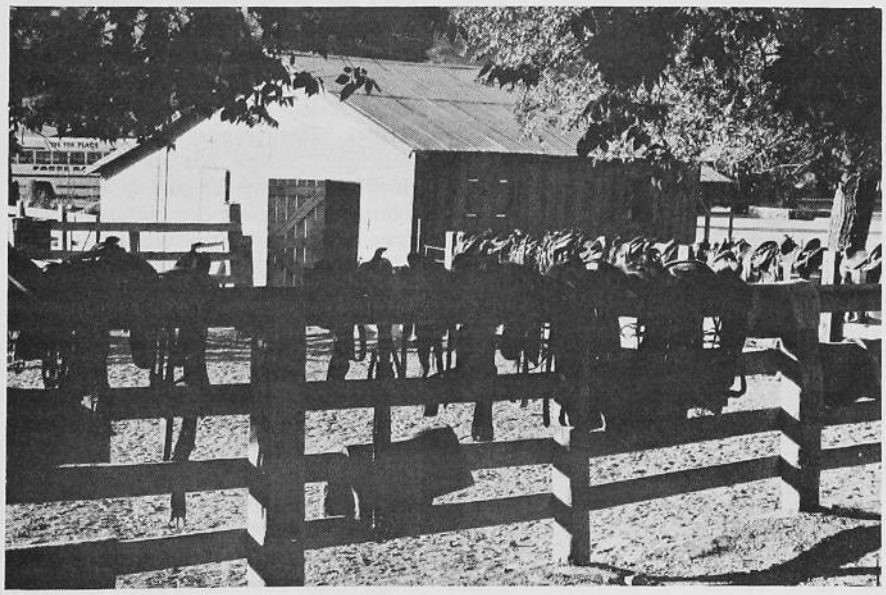


bullet marks in the primary, fired by a mentally-disturbed night assistant some years ago. Ed, Jack, and I took turns photographing each other's reflections in the huge mirror while Joe talked shop with the men working on the telescope.

We got back to the Ranch just in time to catch dinner, and after eating I glanced at my watch and realized 1) that it had stopped, jammed by the dust of Riverside, and 2) that the bus for the evening observing session with the 107″ telescope had already left. "Oh well," I consoled myself, "some you win, some you lose."

As I walked back toward Walnut, Ed drove by, inviting me to continue touring, this time a tour of his own Edmond Halley Observatory. So I went.

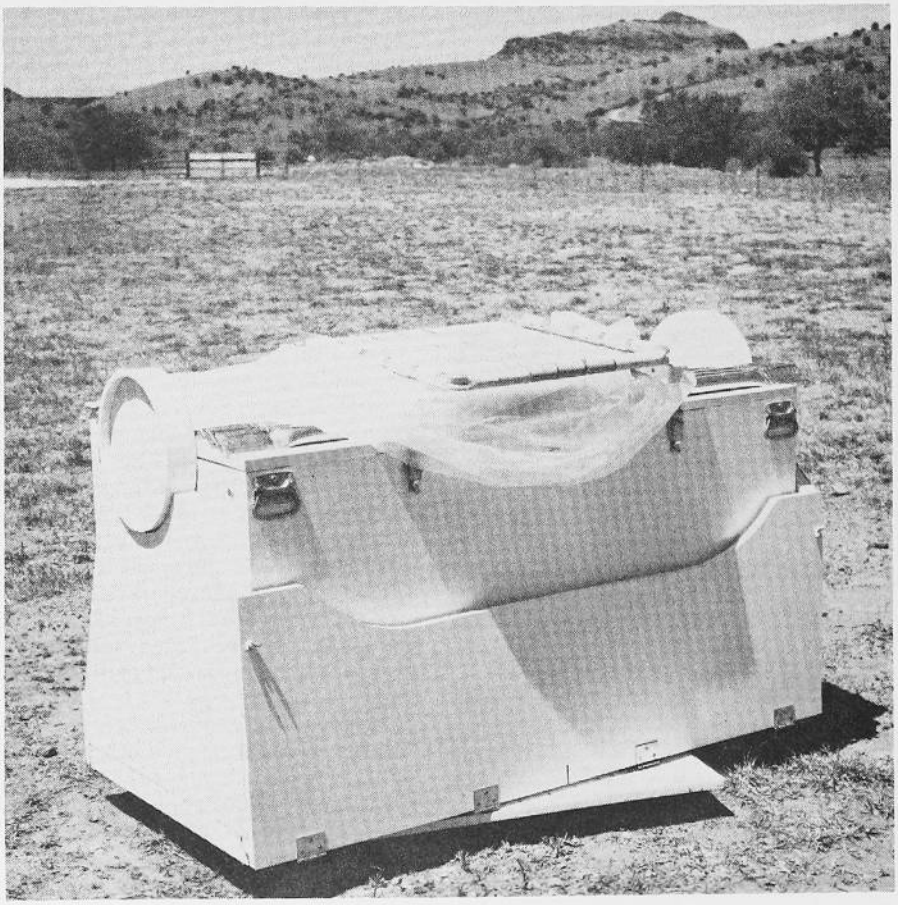
Halley Observatory is located on a ridge just above the Prude Ranch, and features a 16″ Newtonian as its main instrument. As we walked around the outside of the 12′ diameter building, Ed warned us to watch out for scorpions. Argh! Ed, who lives in Alabama, rents time on the telescope to amateur astronomers for $35 per night — a good rate for a largish telescope under dark Texas skies.



As darkness fell, a troop of kids came up the hill for a look through Ed's telescope. I usually have a lot of patience with kids, but on this night I wanted to see what the sky had to offer; I felt like a kid myself. Another observer set up a DS-16 on the crest of the hill, so I joined him. As soon as the first stars became visible, we turned the telescope on Omega Centauri, and continued to view it as the sky grew darker and darker. I observed M-13 for comparison, but there is no comparison: Omega is twice the size and looks three times the size. Whereas M-13 looks ragged, Omega looks smooth. Although I saw this remarkable cluster in a dozen telescopes during the TSP, as well as through an image tube, those first views are the ones that have stayed with me.

Sometime around midnight, we decided to go back down to the main Texas Star Party. Ed's van was fully red-filtered. Not only had Ed put red filters over the headlights, but he had promised to toot "shave and a haircut" on the horn, as a warning to anyone photographing, before turning on those filtered lights. In the end, we decided to be even more considerate, and descended the steep, rocky road with no lights except the van's red-filtered parking lights, in the full spirit of "No Light at the TSP."

I don't know whether it was destiny, or mere happy accident that I stumbled across it as I made my way toward the dorms, but the two hours I spent observing with Lee Cain's 17.5″ binoculars were, for me, the most exciting experience of the entire TSP.



Fantastic Observing...

"The brain believes what it sees with two eyes," says Lee Cain, the builder of what may well be the world's largest binocular. "It's essentially a low-power instrument," he says, but in this case, low power means 80x with a 5.3mm exit pupil, and an 0.8-degree field of view with 24mm TeleVue Wide-Angle eyepieces. It also means impressive views of star clusters, unbelieveable views of bright nebulae, and it further means seeing dark nebulae as they have never been seen before.

The instrument is mounted Dobsonian-style. I found this arrangement nearly perfect for scanning over large regions of the sky — in fact, the urge to scan is all but irrepressible. The binocular itself consists of twin telescopes mounted on a fairly standard but wider-than-normal rocker box, just as one would expect. The structure is largely plywood covered with Formica, giving it a handsome finished appearance at a cost not much more than finishing it with paint would have been.

The twin telescope consists of two principal units, the primary mirror box and the twin upper end, shaped like a figure-8. These units are joined by eight identical aluminum bar trusses Lee made by crushing the tube in a vise and drilling holes in it. The whole telescope knocks down for compact storage and transport (lower left), the upper end unit storing inside the mirror unit just above the mirrors.

The critical problem with large binoculars is obtaining proper image fusion and interocular separation simultaneously. This requires that the optical axes of the telescopes be closely aligned and that the images not be rotated relative to one another. Lee has given these requirements careful consideration.

"The important thing is that the separation of the secondaries be the same as the separation of the primaries," he claims, to an accuracy of about a millimeter. Lee makes final adjustments for image fusion by aligning the primary mirrors. "The primary mirror cells are quite tight," he says. The flotation pads are glued to the back of each mirror, and collimation is done conventionally with three bolts through the back of the cell.

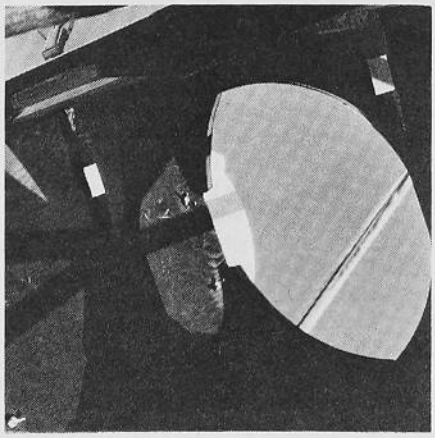
To keep the separations correct, Lee built the upper end unit with a figure-8 shaped piece that carries the two rotating upper ends of the individual telescopes. The construction of the figure-8 unit assures that the separation of the rotational axes of the diagonal mirrors is correct. Three metal fingers center the individual rotating upper ends, and elastic cords hold them to the figure-8 shaped upper end unit.

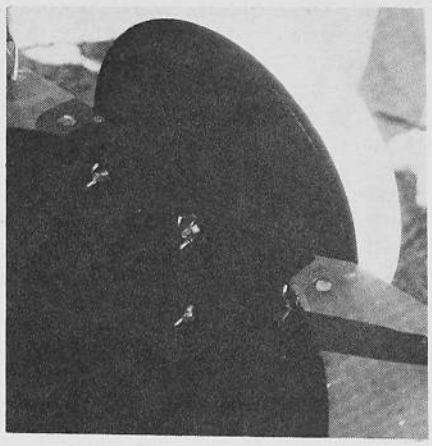
Image rotation is taken care of almost automatically in this design, because the image rotation introduced by the secondary

...with Giant Binox

is cancelled by the tertiary mirrors. Both secondaries and tertiaries rotate when the individual upper sections of each telescope are rotated; these upper sections carry the eyepieces on little extensions and are used to adjust the interocular separation. The secondaries are glued by three spots of silicone adhesive, and collimated by sliding the legs of the spiders in longitudinal slots; each can be rotated.

Both secondaries and tertiaries have 99% reflective coatings applied by Denton Vacuum of Cherry Hill, NJ. "For $150," says Lee, "I picked up 18% more light." High reflectance coating for the primaries is too expensive.





The instrument had attracted a small crowd, so I waited patiently in the line for my first look. The line dwindled; finally the person in front of me finished and stepped aside. I adjusted the separation between the eyepieces — the mechanically easy task of rotating the upper-end assemblies of the two telescopes until the image circles blend — then focused each eye separately.

What followed defies description: I discovered that the quality and sheer realism, for lack of a better term, of an image viewed with two eyes greatly exceeds any monocular image I've seen. It is not a three-dimensional image, or at least that is not the dominant impression, but subtle contrasts and details that disappear when seen with one eye are obvious with two. I don't even remember what that first object was — something fairly faint — because I saw so many more in the next couple hours.

The field of view through the binocular appears as a bowl or dish concave toward the observer, and about one-fourth as deep as it is wide. This effect probably occurs because of a slight mismatch between the magnification of the two telescopes. This means that the focal lengths of the eyepieces — 24mm TeleVue Wide-Fields — or the two Coulter mirrors varied by a fraction of a percent. Since the mirrors had been ordered as a matched pair and polished for Lee on the same pitch lap, the eyepieces are the more likely candidate; in any event the effect is not unpleasant.

For the next several hours, a small group of diehards and I scanned the binocular all over the region of the galactic center. I began, rather modestly, looking for the same dark nebulae I had observed two nights earlier with Dana Patchek at Riverside; I knew roughly where they were. The problem soon became an embarrassment of riches: which of the many dark nebulae visible were the ones I'd seen before? Scanning without plan revealed dozens of these objects — though I did eventually find both I sought. I happened across the Parrot Head, recognizable by its shape, lots and lots of long dark streamers, several fields nearly devoid of stars, including one field near Antares with a single star of 14th or 15th magnitude in it.

Among the bright objects we observed was the Lagoon Nebula, which spilled across the field far brighter than any part of the brilliant Milky Way — a shining fluid enveloping the star cluster embedded in it. Minute runs of dark stitchery crossed it — these dark nebulae also show up in the photographs. The image I saw was indescribably REAL; seeing is, in this case, essential to believing.

On closing one eye, I still had a splendid view, but the subtle impression of the nebular glow as grainless, smooth, silky, and fluid, and the faint western extensions of the nebula, were lost with one eye.

Despite its brightness, I did not notice see any color in the Lagoon, so I was all the more surprised, when I swung the scope up to the Trifid and its companion reflection nebula, to see the Trifid as pink (not red) and the companion reflection nebula as pale blue. I still cannot explain why I could see color so distinctly in this pair but did not see it in the brighter Lagoon, but it may have something to do with the color contrast between the Trifid and its companion which is lacking in the field of the Lagoon.

The dark nebular complex around the Trifid was also immediately visible. I did not expect to see these dark nebulae any more than I had expected the color; if I had not seen these phenomema, I doubt I would have thought to look for them. Nor would I easily have believed that what I saw could be seen if someone else told me that they had seen it.

I could go on and on, but I won't. The only way you can comprehend these effects is to see them yourself. I suspect that people's experience with binocular vision varies considerably, though most of the people I talked to since seem to experience it much as I do. For an idea of what happens, try this: from a dark sky site, compare the appearance of the Milky Way in Cygnus or Sagittarius monocular and binocular (cover one eye with a dark card for the monocular view). Critically assess what you can see with two eyes that you cannot see with one, for both stars and nebulosity. Compare also M-31 and M-33 with one-eyed and two-eyed vision, for the naked eye and with 7x50 binoculars. For me, viewing with two eyes adds about half a magnitude on stars, aids seeing broad, low-contrast features of the Milky Way, and markedly reduces eyestrain.

Lee has talked to optometrists and opthomologists about the mechanisms of vision and image interpretation in the brain. According to them, we are "wired" for binocular vision. In a two-eyed world, the brain rejects many one-eye effects, like floaters, *because* they are seen with one eye only — unconfirmed sightings, as it were. On low-luminosity images of unfamiliar objects, the system edits out or ignores features of the image in which it has the least confidence, including the faint stuff near the threshold of visiblity. As Lee puts it, "the brain *believes* what it sees with two eyes." In the ordinary daytime world, where the brain already knows the scene, it does a lot of "filling-

in" for the eyes, so on familiar objects the monocular view is nearly as good as the binocular view.

This brain-processing of ocular images produces other effects, too. "When I look at Omega through a monocular telescope like a C-11 or John's 12", it seems to boil and writhe," said Lee. "That might be the brain looking for some pattern, but the brightness of the stars at the limit of the 12" mirror is near enough threshold that the brain won't quite believe them, so it shuffles around a little bit." We looked up at the stars again. "The field of view the binocular produces," said Lee, "is solid. It's stable; it doesn't flicker. That's one of the subtler things I've noticed." Perhaps if we were to lavish some of the care on using our eyes that we do with rolls of fast film, we would gain significantly.

The stars of Scorpius and Sagittarius were high, Omega Centauri long set and Capricornus risen, the Milky Way a glowing river dividing the sky when exhaustion finally caught up with me. I don't know how late it was by the clock, but I do know that as I rolled into my sleeping bag, I was profoundly tired and happy.

The stars at night are big and bright...

I slept until 11:30, rising just in time to shower and catch lunch, and then spent the better part of the afternoon examining telescopes in the main observing area and up on the telescope field. The most impressive instrument — featuring a "big polar disk" fork equatorial mounting — was a 17.5" f/4.5 Newtonian built by D. Eric Allen, a contributor to TM#22. This mount has the stability and ease of motion characteristic of the best Dobsonians. His article, on aligning fast Newtonians, had obviously been inspired by the problems of aligning this particular instrument.

Another large instrument that I was sorry to have missed the previous night was Kathy and Gil Machin's 18" Dobsonian. A picture of this telescope appears in last year's TSP coverage. A few experimental nudges convinced me that this 'scope possesses that nice buttery Dobsonian "feel"; I resolved to return to it that night.

When I got back to Walnut, I found Jack Newton worrying about how he could develop the two rolls of VR-1000 film he'd shot in his cold camera mounted on Randy Aulbaugh's C-14 last night and the night before. He had made exposures of Omega Centauri, NGC-5128, and the Trifid Nebula. Jack had come prepared with two coffee Thermoses of dry ice. "It lasts a week," he said, shaking one, "and I've got enough to take more pictures tonight."

My talk, "Amateur Astronomy: Where Are We Going?", was scheduled for 7:30 that evening, so I settled down in the late afternoon with my notes and ran over the talk several times in my mind. Several people asked me what I intended to say — and afterward what I had said — but I begged off. If I get the chance, I'll write it up someday.

After the talk, I thought I'd try making another star party tape. Hearing the anguished squeek-eek, squeek-eek of the dust-filled take-up reel, or seeing starlight glinting off the microphone, people would ask, "What's it for?"

"Realistic dialog," I'd answer, holding the mike toward them, and in the dark they'd soon forget its presence. I also tried "taking notes" about the telescopes I looked through. That tape, a week later, proved valuable as inspiration during the final polishing of this article.

In the early evening the seeing was quite good. The zodiacal light stood out once again in the western sky, but thin horizontal clouds were silhouetted against it. I started down on the main observing area standing in line for Gil and Kathy Machin's 18" f/5 Dobsonian, through which I had an excellent view of M-11. Even at the high power we had on that cluster, this instrument handles remarkably well.

After that, I walked down to examine D. Eric Allen's 17.5" equatorial Newtonian. We aimed it first at Saturn, then at Mars. "This instrument shows more detail on Mars," I muttered into my tape recorder, "than any other instrument I've seen here." Such performance is all the more amazing because we've all come to expect less-than-perfect images from thin mirrors; the performance of Eric Allen's telescope underscores the extreme importance of proper collimation.

When my recorder ran out of tape, I was at the far northern end of the upper telescope field, and talking to a young man concerned that his 10" Odyssey Compact was somehow inadequate. His questions and anxieties suggested that he was suffering from a case of aperture envy brought on by seeing larger telescopes present, and had been led to think that if he had not paid in excess of $1000 or suffered endless nights at the grinding stand, he was not a true amateur astronomer. Then, too, he seemed distressed that his is not a "status" telescope.

Had he not noticed that the telescopes being used by their owners that night were those of relatively modest aperture? "You're one of the lucky ones," I said. "You're free to observe anything you want." At his request, though, I checked the optics in his 'scope, finding the mirror excellent. Images were slightly comatic, but it was still able to split Epsilon Lyrae cleanly despite the poor seeing. I showed him how to tweak up the alignment, assured him that he had a 'scope with excellent optics, and left him happily observing the Cygnus Loop.

Texas Telescopes

By Friday morning the sky was veiled with clouds. Jack had more pictures to develop, and he had used the last of his dry ice. He was pretty excited by the skies and the southern objects, and was clearly having a great time. Of course, he and Jack Marling had been trading trade secrets and politely disagreeing over the respective merits of hypering and cooling.

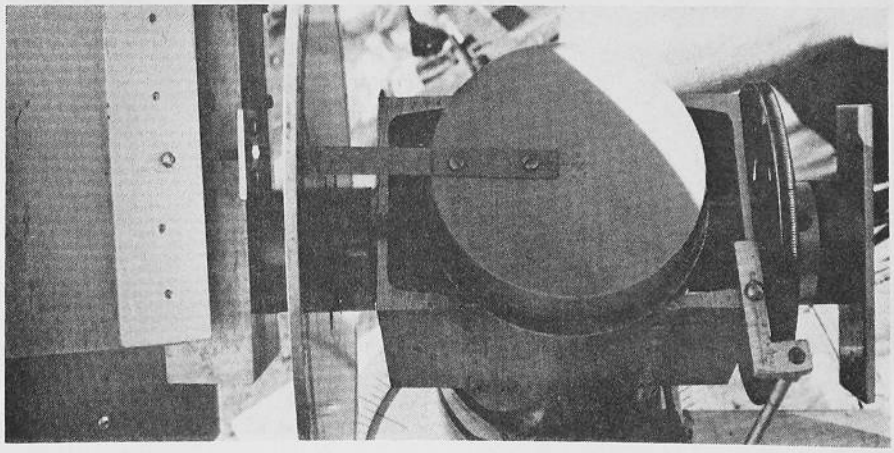
I had been asked to help select the merit award winners; the selection committee was to meet at 10 a.m. near the north end of the upper field. Randy Aulbaugh was in charge; Al Bowen, John Gregory, and myself were the others. We moved from telescope to telescope, talking with the builders. I have already mentioned Lee Cain's and D. Eric Allen's telescopes, the first we examined, outstanding instruments which I suspect will be widely copied. Of the others we inspected, John Love's and Francis Haysbrook's also deserve mention here.

The former was a torque-tube mount carrying a C-8 — would that all SCTs were so solidly mounted! The base of the mount was a 185-pound block of concrete; from it protruded a 1" x 3" aluminum spar over which the 4" diameter torque tube itself slipped, turning on two groups of three standard 1" x ½" ball bearings. John said, "there's zero machining on the inside of that tube," as if he were pleased to have gotten away with something. What impressed me was that a solid thump on the side of the telescope tube died out almost instantly. The whole thing had a grab-bag feel about it, the feel of something made from whatever's on hand. John didn't deny it; indeed, he said the mount wasn't finished — "a work in progress." But I don't think he wanted to finish it, because then there would be nothing left to do.

Haysbrook had entered an entirely different kind of beast in the contest. He had constructed a compact folding tripod for a standard 8" SCT — and although the design was sound, it was not unusual. What struck us as remarkable was his use of only a lathe, handtools, and skill to manufacture his finely finished tripod. Years ago I worked closely with a machinist, a Yorkshireman who served his apprenticeship during the war in the British shipyards. "We trained on big

Concrete Solidity...

John Love's torque tube mount is as solid as they come, passing the "thump test" with nary a shiver, and the design permits excellent access to the 8" SCT mounted on it. The tube is 4" in diameter with a ¼" wall, unmachined inside, and turns on two sets of three ball bearings. Both axes are driven, though John has had some difficulties with backlash in the RA drive gear, which he expects to solve. The concrete base of the mount can be bolted to a massive pier rather than the stack of standard concrete blocks John had at the star party.



A Big Equatorial with Teflon...

Who says you can't make a great equatorial mount from plywood? D. Eric Allen of Oklahoma City, OK has done so, and done so beautifully. This 17.5" f/4.5 reflector is nearly as compact a mounting as the best Dobsonian, but offers the potential for tracking. And, unlike many of the steel-fabricated forks I've seen, Allen's all-plywood fork is not only solid but also very well damped.

The equilateral polar cone is built from a disk two ¾" layers of plywood thick, rimmed with a ¼" aluminum track and a polar cone of eight ¾" plywood triangles. The southern end of the polar axis is a length of aluminum pipe (right) held in a split Teflon-lined wooden pillow block.

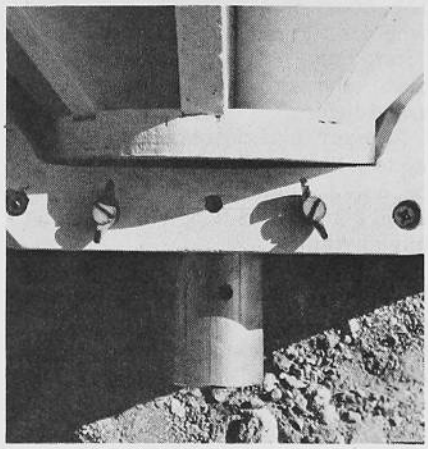
The fork arms are also two layers of ¾" ply thick with additional bracing at the lower end. The declination bearings are also aluminum pipe running in Teflon-lined pillow blocks. Teflon pads inside the fork prevent lateral movement of the telescope; these run against Formica on the side of the tube box.

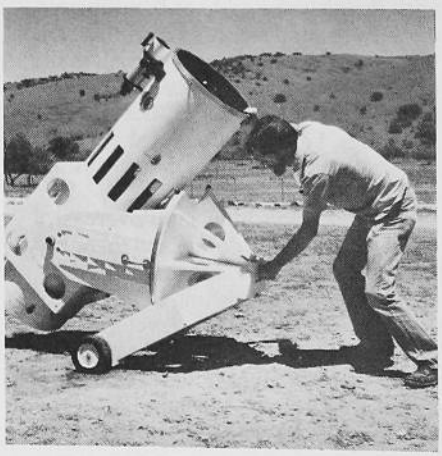
The tube is fully rotatable within the box, and runs on Teflon. For portability, the tube separates into three sections: the mid-

...Smoothness

section stays in the tube box while the mirror cell and a third containing the diagonal and focuser travel in his car.

The mounting allows 7½ hours of movement in RA, and access within 8° of the southern horizon by means of a cutout on the polar disk. It weighs 245 pounds and takes about five minutes to set up. Wheels permit moving the assembled telescope short distances.





lathes and mills," he once told me, "but y'know wot the final test they gave us was? We had t' make a bloody perfect square hole with a file."

Right after lunch, Ed Boutwell and I took Haruo Fujitsuka, a Japanese photo-journalist on assignment for *Tenmon Gaido*, the major magazine for amateurs in Japan, to McDonald Observatory for a tour of the big telescopes. I wanted to see them again, but this time, unlike the first, I had slung my camera bag on my back.

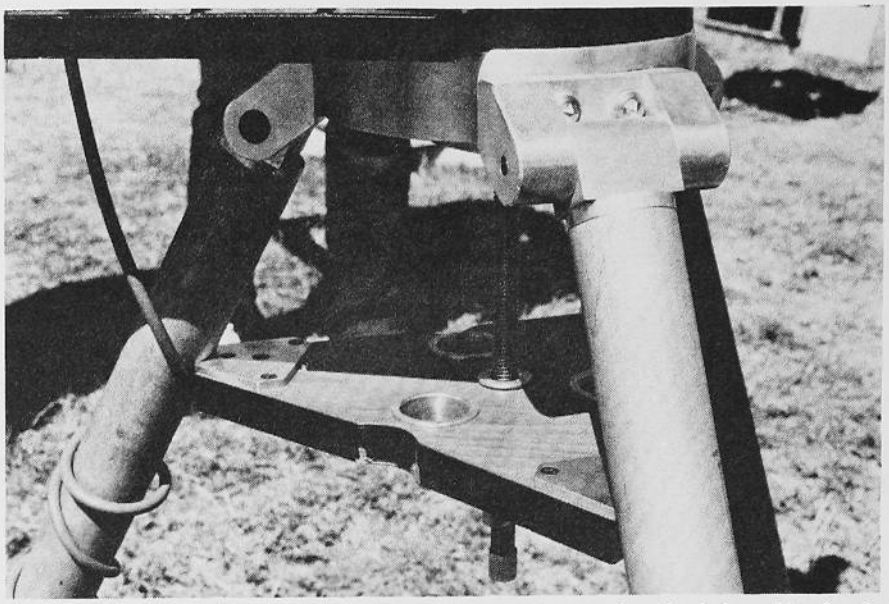
Once again Ed charmed his way into the innnermost recesses of the observatory; both Haruo and I got our pictures. Haruo's were of people posed in front of telescopes; mine were of that magnificent 82" reflector. I love the character of the 82-inch with its nine-foot setting circles divided into single minutes of RA almost a quarter inch apart, the long polar axis, and the great dark bulk of the mirror cell suspended above the observing platform. I climbed the dome stairs to the very top and took pictures nearly straight down. If ever they want to get rid of this instrument, they'll have a willing taker in me.

While we were in the dome, cumulus towers built into thunderheads. Across the rolling plains we watched rain falling and lightning sparking between the clouds and ground some ten miles away. When rain began falling on the mountaintop, we headed back to the Ranch.

That evening, David Levy had assembled a disparate crew for dinner: himself, me, Norm Sperling, Gary Rosenbaum, Pete Manly, and Kathy Hedges. Off we went to a nice little resturant in the state park, a mile or so down the road. The park looked beautiful; sometime, I thought to myself, I've got to come back to this place, or some other spot near here, for some quiet observing by myself.

The evening's speaker was Dr. Gerard de Vaucouleurs from McDonald. He is a small, quiet man — extraordinarily so for one who deals with the distance scale of the universe, or perhaps modest because of that. His topic was the motion of the Earth in the universe and the dependence of internal motion on the scale of the moving structures. I longed, afterward, for clear skies to search for some of those distant clusters of galaxies.

As the sky was now solid overcast, I walked back to the dorms and there had a long talk with Haruo. Meanwhile, Jack Newton was rushing in and out of the bathroom. He had developed the VR-1000 he'd shot in his cold camera on the previous nights, and was now preparing positive transparencies by copying frames of VR-1000 in a slide copier onto Kodak 5072 high contrast negative copy film. The bathroom was full of pint bottles of color chemistry and scraps of 35mm film. It seemed like an awful lot of work, but before we retired that evening Jack had produced fantastic transparencies of Omega Centauri, NGC-5128, and the Trifid Nebula. "Sure, the pictures are great," Jack noted, "but what I find really amazing is that there were hundreds of people out there on that field while I was making the exposures and nobody was shining lights around. Everybody is so considerate."



Close-up of Francis Haysbrook's tripod for an 8" Schmidt-Cass., made with a lathe and hand tools.

And that, I mused as I rolled into my sleeping bag, is one of the things that distinguishes the Texas Star Party from the Riverside Telescope Makers Conference.

The Last Round-Up

Morning arrived gray and cloudy. After a rather prolonged breakfast, I talked over coffee with Deborah Byrd. Debbie is the originator of PBS's "Stardate," and used to write for ASTRONOMY before she got so busy. She noted that someone had asked whether the show's title came from "Star Trek," "which, of course, it does," she said, "but no one had ever asked before."

After my third cup of coffee, I walked up to see where the swap meet would be, only to find it already in progress. I will admit I was tempted, but didn't buy anything.

Next came The Group Photo. We all lined up on the tippy rocks at the side of the football field, then moaned and groaned while the photographer readied his 4x5 camera and made four exposures.

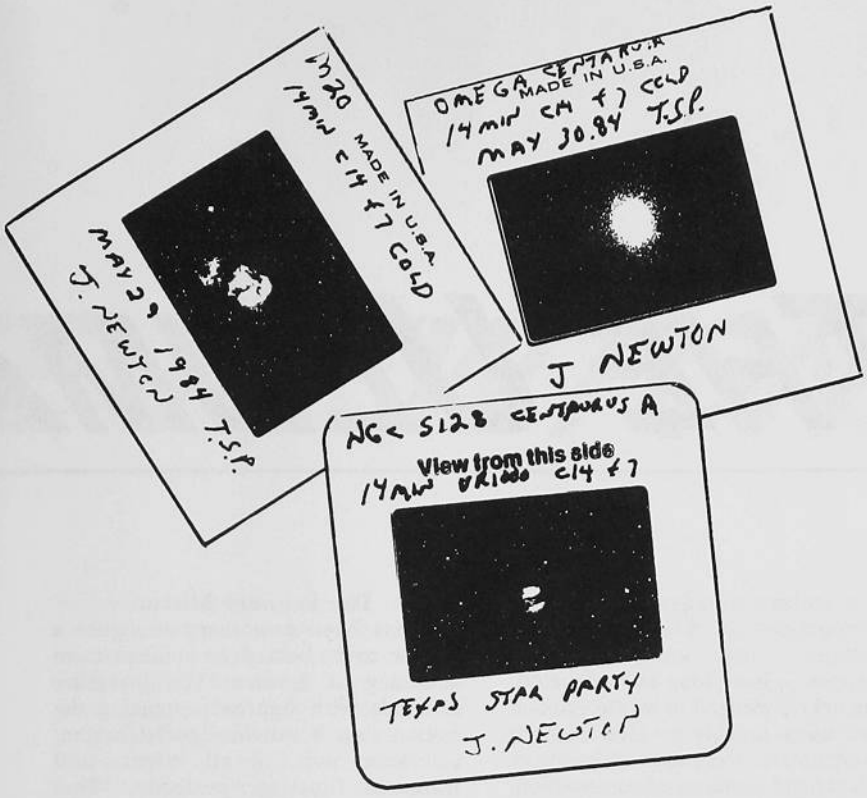
In the afternoon, I went to the Sun Session — presentations by solar astronomer Jay Pasachoff, speaking on his favorite topic, and videoptapes and photographs of the annular eclipse by several successful groups. I am sure that the tapes weren't as good as being there, but they were, nonetheless, spectacular. Since the weather had been good along much of the eclipse track, I knew that by the time I got back to ASTRONOMY, I'd find a carton full to overflowing with slides, prints, and hopeful cover letters.

Two clear nights, talking, telescope judging, and trips to McDonald had brought my reportage to a halt. I decided that it was time I started to write again. Toting my computer up to the commercial displays building, I settled down in a comfortable chair to pound the keys for a satisfying couple of hours, 'til time for supper.

After dinner, even though the hall was filled, people continued to drift in. George Ellis stood in front of the crowd.

"It is our custom," he said, "to feature a speaker who captures the mood and spirit of the Texas Star Party, and this year, I am proud to introduce Ben Mayer, tonight's speaker."

"What George so graciously gave me credit for," began Ben, "is serendipitous discovery." It sounds funny to say that Ben's topic was life, death, and the universe, but, dammit, that's what it was and he did it superbly. It was the same talk he had given at Riverside, but this time a more refined presentation, smoother, rhetorically developed, with a different emphasis. Ben uses the double entendre as a device to wrench his audience from the expectations and conventions of normal discourse, preparing the way for less discussable topics: life, death, and our place in the universe. "The stars," he noted, "are



the last thing in this world that are for free." Ben made the rather delicate point that astrology is useful to astronomers, too, if only they would use it. "It will help us," he said, "get others into our magic sandbox to play with the stars."

When the applause subsided, George called, "Ben, come up here again," and placed a Texas Star Party cap on his head. "You gotta take this to Stellafane this summer," he said, then called Jay Pasachoff, and Jack Newton, and me for our TSP caps, too. Awards ceremonies are usually pretty dull affairs; but George and TSP crew ran it with something I still can't place my finger on, making it one of the most gracious I've even seen.

Randy Aulbaugh awarded, "to the entries that are particularly interesting," certificates of recognition to Lee Cain, for his 17.5" binocular; to D. Eric Allen for his his 17.5" conic polar axis fork equatorial, commenting, "there's always a better way and sometimes that way is simplicity"; to John Love, "a master at using junk," his award "for the contruction of a functional mount," given "as much for creativity and innovation" as for the mount he built; and finally recognized the craftmanship of Francis Haysbrook's tripod: "it's even more beautiful when someone has taken the time to work with his hands." Each winner received a certificate and a year's subscription to TM.

As those who had come the farthest — from Tokyo — Haruo Fujitsuka and Yasumaro Yaita received awards that I don't think they had expected. The photo contest winners were Edgar Everhardt, Jack Newton, Robert Reeves, and Keith Shank, with special awards to Edgar Everhardt and to Jack Newton for the picture of the Trifid he had made just two nights before.

John Wagoner announced the winners of the observing Olympics — third place, with 76 objects, to John Cotton; second place, with 78 objects, to Matt Delavoryas; and first, with 248 objects, to Michael McCants. Each winner received a certificate and a year's subscription to *Deep Sky*.

"There is a very special place in our program," said George, "to recognize someone known for his observing — and this year the award is about 30 years overdue." The Texas-shaped "Lone Stargazer Award" went this year to Oscar Manning for his observing dedication during the 1930s.

Deborah Byrd, the founder of the Texas Star Party, received the Omega Centauri Award "for service to all of amateur astronomy." Too pleased or surprised to say much on this occasion, she simply smiled her big smile.

Ed Boutwell won a special award for losing the keys to his van — receiving the key back attached to a 10-pound weight. He said that the award proves Boutwell's Axiom, "If you don't make a fool of yourself, your friends will do it for you." Ed then, to general cheering from the crowd, announced that John Robert Prude had decided to remove all the vapor lamps from the Prude Ranch.

Finally the evening progressed to the Great Texas Giveaway. Beginning with a copy of the *Hubble Atlas of Galaxies*, won by Jack Newton, "the handsome and erudite Mr. Al Bowen," as George dubbed him, supervised the distribution of dozens of prizes from AstroCards, AstroTech, the Sleeping Lion, Everything in the Universe, S&S Optika, TeleVue, Orion (I won the 20mm eyepiece — thanks, Orion!), Lumicon, and two grand prizes, an 11x80 binocular from Celestron and a 1000mm f/11 telephoto from Meade.

And then it was all over. Outside the rain poured down — the Prude Ranch getting one-third of its annual rainfall during that fourth night of the Texas Star Party. I hung around talking to people in the hall, unwilling to admit to myself that it was all over, and that tomorrow I'd be flying away.

Home Again

A week, two weeks later, the Riverside and Texas Star Party still loom large. "What's the difference between them," people ask, meaning, "Which one should I go to?" The two meetings are quite different, and very hard to compare. Riverside is the telescope meeting, yet I saw some of the most interesting telescopes on my trip at the TSP. And TSP, the observer's meeting, was in some ways the less observationally acute event. But Texas skies are better. Riverside has three times the attendance of the TSP, though the TSP is the more pleasant for its smaller size. And despite the fact that many of the speakers at the TSP represent firms actively selling merchandise to the amateur, Riverside is by far the more commercial. As to which you should attend, that's your choice; they're both informative, and both a lot of fun.

"And what about Stellafane?" they ask. Stellafane is short — one evening plus one day — versus three days or four. And Stellafane is primarily people and tradition, not telescopes or skies. Yet all three share telescopes, people, and skies, and each, as we all know, varies from year to year.

But above their differences and beyond their similarities, these meetings are places where we come to learn what others are doing and share with them what we ourselves are doing. I saw and learned a lot this year, and I hope that if you were not able to travel to these meetings, you'll feel you have gained something from my having attended and written about them.

— *Richard Berry*

■

THE ULTIMA

The relative advantages and disadvantages of reflectors versus refractors — and now catadioptric telescopes — have long been debated. While acknowledged to be superior in several ways, notably the total freedom from chromatic aberration and relative simplicity and economy of construction, reflectors have been justly faulted for coma (owing to their typically short focal lengths), instability of image (caused by internal tube currents), and subtle loss of definition and contrast on delicate objects (because of the diagonal mirror and its mechanical support system). Much can be done to de-emphasize or eliminate these faults — and in so doing to achieve a level of performance that challenges the refractor's most desirable characteristics. Instruments designed with care can incorporate the best of both types.

Our technique for converting an ordinary Newtonian into an ultimate Newtonian is similar to design techniques currently being applied in the field of audio technology. The quality of audio systems, recording techniques and instrumentation has improved greatly in recent years because close attention is paid to improving each and every component — a little bit here and a little bit there — for the good of the overall signal-to-noise ratio. Optics are like audio in that the leakage of anything other than the source into the system degrades the resulting image. What we are looking for in a good telescope is an image free of distortion and distracting "noise." I will discuss, point by point, those aspects of design and workmanship which I believe can collectively contribute to a state-of-the-art Newtonian.

The Primary Mirror

It has been customary to figure a mirror, to the best of our abilities, to an accuracy of ⅛-wave. The literature abounds with figures supporting the notion that a mirror figured to that tolerance will, to all intents and purposes, function "perfectly." That tolerance is also the generally accepted limit of the reliability and accuracy of the Foucault test. It is difficult for most workers to swear to, or agree among themselves, on a reading to a tolerance less than 0.015″. For mirrors of normal length, it is difficult enough to be certain that one has figured the mirror to within the desired tolerance. However, with mirrors of longer focal length, say f/10 to f/12, reading the Foucault tester to an accuracy of 0.020″ means that the realiability of figure can be judged to an accuracy of around ⅛₀-wave.

Discussions of 6″ or 8″ long-focus mirrors in the standard texts tend to be misleading because they place undue emphasis on the difficulty of reading the shadows on account of their extreme delicacy. The experienced Foucault reader can readily familiarize himself with the appearance of these shadows by masking off the central 6″ diameter of a 10″ or 12″ mirror with a 60″ to 75″ focal length and learning what long-focus shadows should look like. These same books also mislead by underemphasizing the difficulty in the actual figuring of the glass. A long-focus mirror of just the right curve is difficult and requires much care in the working, but it is not that difficult for the eye to judge.

But why invest all the extra time and care in figuring a long-focus mirror, especially when one bears in mind the extra difficulty in mounting a telescope

TE NEWTONIAN TH

with a long tube? For me, the reasons are the greater accuracy of the figure, the increase in definition (a function of focal length), the reduction of coma to an imperceptible level, the greater magnification and resulting eye relief with ordinary eyepieces, and the opportunity to use as small a diagonal as possible, which reduces image-degrading diffraction.

And why attempt to surpass the ⅛-wave tolerance commonly accepted? Certainly it is unnecessary for telescopes in which the secondary mirror and its support system introduce diffraction in excess of anything that would be gained by greater finesse in figuring. In a mirror figured to a surface accuracy of ⅛-wave, 68% of the light energy from a point source will be concentrated into the central Airy disk, and the remaining 32% will be distributed into a system of surrounding rings. With the theoretically perfect mirror, which I feel we should attempt to approach as closely as possible, 84% of the light will be concentrated in the central disk and the remaining 16% in the rings. That's half as much "noise"! That, I believe, accounts for the superiority of definition and contrast in lunar and planetary detail achieved with finely figured mirrors.

Furthermore, the ⅛-wave tolerance standard applies to the resolution of point sources (stars), whereas the Moon, planets and nebulosities are extended objects whose images profit in terms of contrast, crispness and information content when the many diffraction patterns that combine to form the image are as perfect and noise-free as possible. Being aware that a long-focus parabola and sphere often fit within the same tolerance envelope, and therefore both satisfy the Rayleigh criterion, some workers might be inclined to forgo figuring a long-focus mirror, feeling that the sphere is "good enough." It has been my experience that this approach prevails among those whose final surfaces are not even *that* good. For those really serious in their quest for the ultimate telescope, the figuring of the long-focus paraboloid can be seen as an unparalleled opportunity and challenge to make the finest possible surface that the hand of man can make. Additionally, great care should be exercised in avoiding scratches, greyness, pits and micro-ripple so as to avoid the degrading effect on the image of light scattering.

Substrate Material

Mirrors made of Pyrex cannot be described as capable of reliably and accurately holding an ultra-precision figure. It is particularly important in the case of the long-focus mirror to select a substrate material with the lowest possible coefficient of expansion, since the shallower the curve the more sensitive it is to variations in temperature during a typical observing session. Furthermore, there are grave difficulties in trying to put a delicate paraboloidal surface on a substrate which may, over an hour or so, transform itself on the test stand from an oblate spheroid to a hyperboloid while equilibrating. The material of choice, therefore, is ULE Titanium Silicate which, with a coefficient of expansion of $.03 \times 10^{-6}/°C$, is roughly 100 times more stable than Pyrex, and therefore capable of honoring the finest figure we can put on it. Zerodur 3 is the second choice. Both are easily worked and permit great control during figuring due to their stable characteristics on the test stand.

The Secondary Mirror

Perhaps the greatest single drawback in the Newtonian design is the secondary mirror. This not only dims the image because it obstructs a portion of the incoming light — not to mention the support system, usually a spider, which adds insult to injury — but the obstruction throws more energy ("noise") into the ring pattern of the diffraction pattern.

Most of the literature on telescope making cites the desirability of restricting the central obstruction to less than 6% the area of that of the primary mirror. I believe the rule should be revised to read either "as small as possible" or "⅛ the diameter of the objective or less." The closer you can get to eliminating it, the better.

To appreciate the degrading effect of the spider vanes, one has only to look at a bright object, such as Jupiter or Venus, at low power. Witness the spikes emerging from the central body. It is true that when we increase the magnification to a certain point, these spikes are no longer so apparent, but that light is still present and forms a veil that affects threshold definition and interferes with the observer's ability to detect delicate contrast and color differences.

We can reduce the size of the central obstruction by increasing the focal length of the primary mirror, reducing the distance between the eyepiece and the secondary by using as short a focusing assembly as possible, and using a fully illuminated field no larger than necessary for the observation planned for the telescope.

Finally, there *is* a way, although costly and requiring extra work, of eliminating the spider or other secondary support

LTIMATE NEWTONIA

system. By using a plane-parallel optical window to support the secondary diagonal mirror, roughly 21″ of diffraction-producing, image-degrading edges in the four-vaned spider can be eliminated. However, the quality of this plate must be such that it does not introduce problems of its own. The specifications for this piece of glass, the qualities it must have so that its existence is not perceptible, are several: it must be made of a high-quality material, such as grade A annealed borosilicate crown with a perfectly uniform refractive index; both sides must be flat to considerably better than ¼-wave; both sides must be parallel to within 30 seconds of arc; and the glass must be of sufficient thickness that its figure will not be affected by its own weight or the strain of supporting the secondary. For best results, you should have it anti-reflection coated on both sides with a material such as magnesium fluoride so that its only fault is the inconsequential loss of light in the glass itself. [The new English edition of Texereau (Willmann-Bell) has considerable material on making windows. —ed.]

Whether the fabrication of this plate and its cell are worth the effort or expense is a decision the builder will have to make, but remember that such a plate serves three other purposes: it seals the telescope from bothersome air currents and thereby confers on a reflector the advantage which has long been a major selling point for the refractor; it protects the inner optics from light-scattering dust; and it greatly prolongs the life of the reflective coatings on the Newtonian's two surfaces by reducing attack by atmospheric impurities. We've already begun to incorporate some of the best features of the refractor while losing none of the advantages of the reflector.

The Eyepiece Holder

It is also necessary, I feel, to revise our attitudes about the eyepiece holder, a part of the telescope pretty much taken for granted. Currently available eyepiece-holders are generally extend 3″ to 4″ from the tube even in their racked-in position. The reason for this design, according to several manufacturers, is to compensate for errors in drilling holes in the telescope tube; the extra length provides leeway for the less-than-careful. The result is that unless you make it yourself, you must settle for a commercially made one that requires a larger secondary mirror than necessary. Clearly, then, the fabrication of short eyepiece holders, in the neighborhood of 1″ to 1½″, is a top-priority feature of the ultimate Newtonian.

Another important consideration should be that, when focused, no part of the holder or eyepieces intrudes into the light path, thereby introducing a big dose of diffraction. I'd suggest a combination rack-and-pinion plus helical system to allow fine focusing necessary to get the most out of the telescope one has labored over so long.

Blackening the Optical Train

Sometimes overlooked, yet nonetheless extremely important and relatively easy to accomplish, is blackening, insofar as possible, all points along the optical train. To begin with, the inside of the tube should be coated with a layer of black velvet. It is also important that the inside of the eyepiece holder and the tubing of the eyepieces themselves be as dull a black as possible, especially in the case of the Barlow.

An extra length of tube at the front of the telescope helps cut glare and at the same time serves as a dew cap for a plane-parallel optical window. The eyepiece holder should fit snugly into the tube, eliminating the leakage of unwanted light or air into the tube.

A nice refinement, and one which mimics the baffling in a high-quality refractor, is to enhance the eyepiece holder/focuser assembly by the inclusion of a variable iris diaphragm indexed so as to match the exit pupils of selected eyepieces. The idea is that nothing other than the mirror is seen by the eyepiece. It is a pleasure to look through the empty eyepiece holder of this type of telescope and see the primary, with its small diagonal reflected in the center, surrounded only by pitch-blackness.

A significant new development in the manufacture of eyepieces is the introduction of multicoating, the kind of subtle amelioration that fits nicely into our plan to achieve a meaningful improvement in performance through an accumulation of small victories. It pays to purchase the finest available eyepieces to match the capabilities of your instrument.

Collimation

The final detail, which sometimes gets taken for granted, is the alignment, or collimation, of the elements in the optical train. The long-focus telescope is rather forgiving in terms of collimation, but once again, this should not be seen as an excuse for sloppiness, but rather an opportunity to tweak the instrument up to an unusually high level of perfection. The importance of collimation and ease with which it can be accomplished by proper instrument design cannot be overemphasized.

Making sure that the eyepiece holder is perfectly perpendicular to the tube, either through adjustment or at the time of assembly, is one way of reducing problems.

Another is a cap for the bottom end of the tube. In addition to such obvious benefits as eliminating stray light from around the mirror, a bottom end cap also functions to keep curious hands off the collimating screws and thereby helps to maintain collimation. At the beginning of every session, before observing, remove the cap for a short period and turn the tube assembly mirror end up to allow warm air to escape. It is necessary therefore that some provision be made for repeated smooth and easy fitting of this seal to the tube.

The finishing touch for the ultimate Newtonian, although rather expensive, is the application of the new enhanced reflective coatings. These make the telescope considerably more efficient than normal. In the case of two aluminized surfaces: 88% x 88% = 77% for aluminum, compared to 98% x 98% = 96% for enhanced coatings.

I am confident that the notions I have outlined here will result in a high-quality instrument and some exciting visual experiences. When viewing through a telescope of this type, one is immediately struck by the velvety black appearance of the sky. The delicate delineation of the dark lanes of the Andromeda Galaxy is awesome as are the crisp yet subtly-colored images of spike-free planets suspended in space. Mountains, craters and other lunar features are incredibly sharply etched, and enjoy an extended scale of tonal values. The shadow a lunar mountain casts is really black! Although such an instrument represents a considerable investment of time and money, one look through an ultimate Newtonian will spoil you for anything less.

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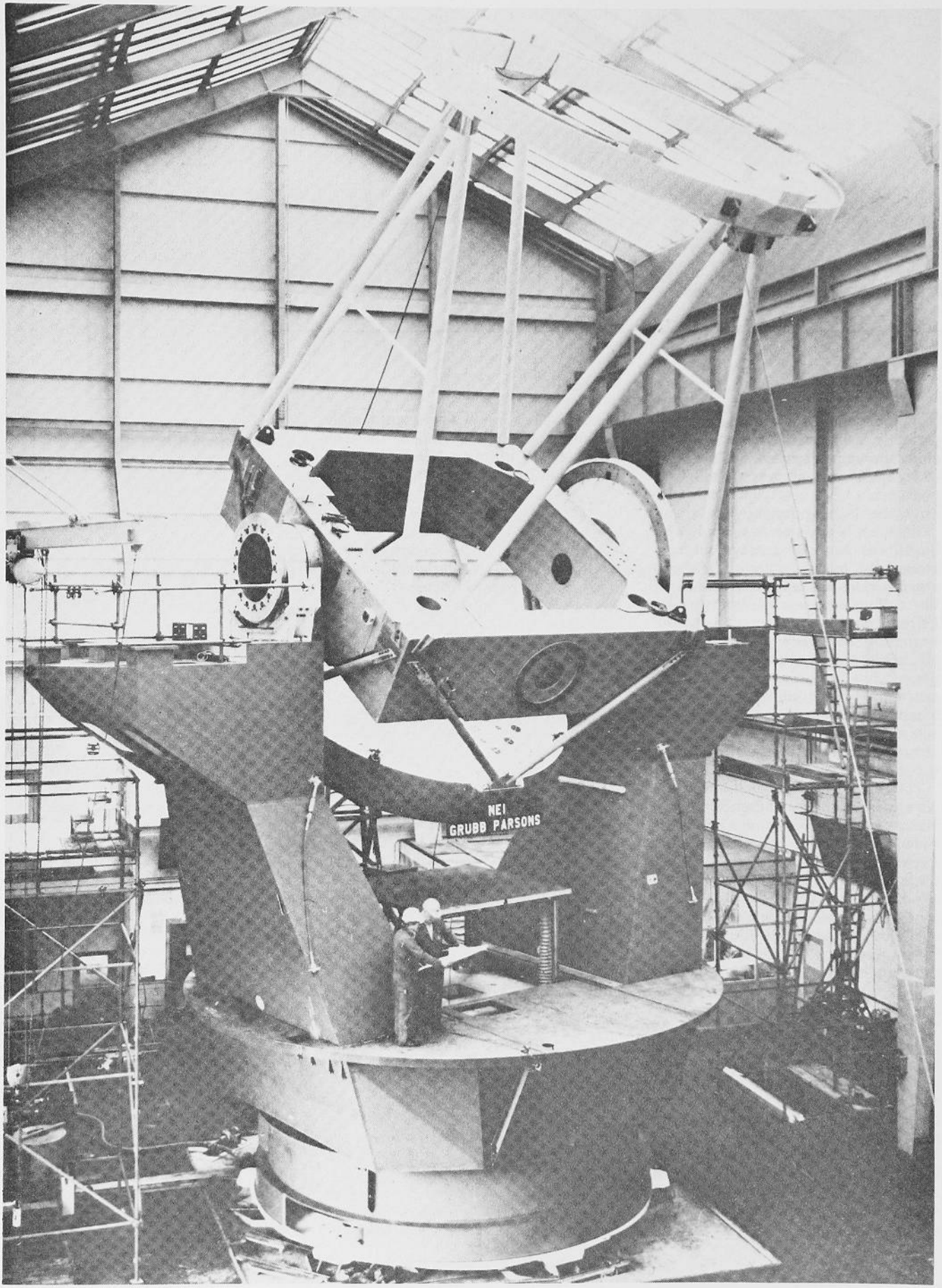

NEI
GRUBB PARSONS

el Observatorio del Roque de los Muchachos

by Alec Boksenberg
Director
Royal Greenwich Observatory

In the next few months, British astronomers will start to observe with new telescopes at the world's most modern observatory, now being constructed on La Palma in the Canary Islands. The observatory is an example of collaboration in scientific research at the highest international level. The telescopes re-emphasize the United Kingdom's place at the forefront of research in optical astronomy.

In brief, the observatory is the initiative of four European countries — Spain, the UK, Sweden and Denmark. The telescopes include the large Isaac Newton Telescope, moved from its original site in Sussex and completely refurbished, and a brand-new smaller telescope for taking wider-angle photographs. Another telescope currently nearing completion, the William Herschel Telescope, will be the world's third largest single-mirror telescope when it is installed on La Palma in three years time.

All three telescopes were built in Britain. A joint British-Dutch team will operate them, and observing time will be shared with Dutch astronomers. There will also be participation by observers from the Irish Republic. The telescopes have been designed for remote control, and it is planned that astronomers will be able to operate them from the United Kingdom some 3,000 km away.

A fourth telescope, the Carlsberg Automatic Transit Circle, is a joint British-Danish venture for the automatic precise measurement of star positions.

The U.K.'s Resurgent Role in Astronomy

The new telescopes on La Palma will re-establish the United Kingdom's leading role in optical astronomy and so complement the country's world-class position in most of the major branches of astronomy — especially radio, infrared, X-ray and theoretical research.

For more than three centuries, the Royal Greenwich Observatory (RGO) has been a center of excellence for astronomical research. Its purpose was originally to study the positions and apparent motions of the stars. These observations were required to find longitude on the Earth and in measuring time (hence the Greenwich Meridian and Greenwich Mean Time). Since the end of the last century, the Observatory's role has widened to include astrophysics — the study of the properties, constitution and evolution of the stars and, more recently, of the galaxies and quasars. That interest led to the construction of a large telescope — the Isaac Newton Telescope — completed in 1967. The changing emphasis was largely responsible for the transfer of the Royal Greenwich Observatory from the Admiralty to the Science Research Council (now the Science and Engineering Research Council — SERC) in 1965, and for the Royal Greenwich Observatory's taking on the responsibility of providing telescope facilities for use by the whole of the astronomical community.

RGO has not only operated the Isaac Newton Telescope for its own astronomers and those from British universities, it has also collaborated with university researchers in developing some of the world's most sensitive detectors of light for use on optical telescopes, providing a continuity in development that university research departments cannot always maintain. In addition, the Observatory has built up a first-class group of astrophysicists.

In recent years, astrophysicists have become interested in objects which appear very faint optically; optical astronomers need large telescopes to pick up adequate light from such objects. Most important observations of faint objects have thus far been made with the large optical telecopes in the United States and, more recently, with the Anglo-Australian Telescope in New South Wales (funded jointly by SERC and the Australian government) as well as other large telescopes around the world.

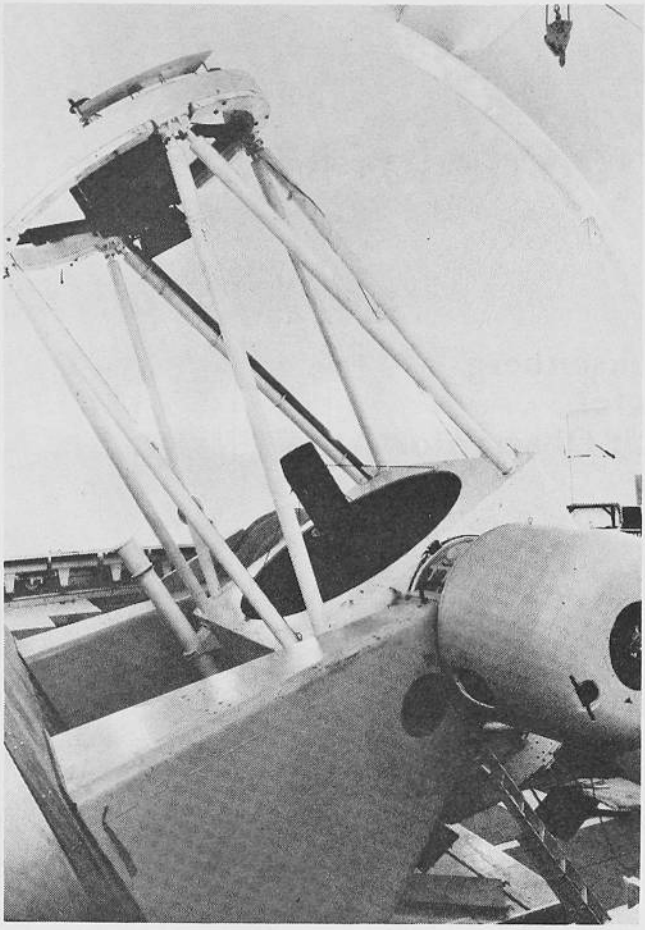
British astronomers have thus planned a new, very large telescope, the William Herschel Telescope, now being built under the management of the RGO. It will be placed on the summit of La Palma, one of the world's best observing sites. This telescope will bring British optical astronomers back to the forefront of world research. The William Herschel Telescope has a main mirror 4.2-meters across, making it the third largest optical telescope (of those with a single main mirror). Equipped with new light detectors from the Royal Greenwich Observatory, its performance will be second to none.

An observatory needs more than one telescope, however. Many astronomers can solve their problems with a smaller telescope, so the William Herschel Telescope will be backed up by the 2.5-meter Isaac Newton Telescope (INT), moved from Herstmonceux. The INT can take spectra of brigher objects which do not need the full power of the William Herschel's giant aperture. For measuring star positions, which is still important (for example in identifying the dim counterparts of radio and X-ray sources), a smaller telescope is available. This has a mirror only 1 meter across, but a wide field of view. Finally, the Anglo-Danish transit circle will carry on the Royal Greenwich Observatory's original task of refining the positions of the brighter stars.

SERC is funding the telescopes on La Palma because they will bring in first-class research results. This is in line with the Council's policy of promoting facilities of high standard rather than spreading support so widely that no one project receives sufficient funding to reach world-class level. SERC (and before it, SRC) has long supported the radio astronomy observatories at Cambridge and Jodrell Bank, both world-leaders. It has more recently funded the world's largest infrared telescope, the United Kingdom Infrared Telescope on Hawaii. This telescope's parent organization, the Royal Observatory, Edinburgh, is now one of the world's leading centers for infrared astronomy and will blaze a new trail with SERC's next ground-based telescope, the Millimeter Wave Telescope, also on Hawaii. This new kind of telescope will probe the universe at the still-unexplored wavelengths between infrared and radio.

The United Kingdom's ground-based telescopes are complemented by instruments above the atmosphere, designed for detecting radiation that is absorbed by air. SERC-supported university researchers, principally at Leicester and University College, London, have pioneered the study of X-ray astronomy. They have kept at the forefront with their involvement in satellites like the European Exosat, launched early in 1983. British astronomers also have an

The 4.2m William Herschel telescope at NEI Parsons.



The re-engineered Isaac Newton Telescope installed at La Palma.

important stake in the two satellites investigating the Universe at ultraviolet and infrared wavelengths — the International Ultraviolet Explorer and the Infrared Astronomical Satellite. The latter was controlled from SERC's Rutherford Appleton Laboratory in Oxfordshire. Though it ceased at the end of 1983, its data will take almost a decade to analyze.

On the interpretive side, university astronomers and research staff at RGO and the Royal Observatory, Edinburgh, have kept Britain to the fore in theoretical astronomy — especially in cosmology, the study of galaxies, and the violent explosions of quasars within them.

Astronomy is a science in which the United Kingdom has come to the fore. The telescope on La Palm consolidates the British lead by providing unequalled facilities for optical astronomy. The telescopes reinforce the Royal Greenwich Observatory's traditional role as a leader in observational astronomy, as well as in instrument development and astrophysics studies. The La Palma telescopes will spearhead the thrust of British astronomy into the twenty-first century.

The Roque De Los Muchachos Observatory

The telescopes are sited on La Palma, one of the smallest and least populous of the Canary Islands, lying at the western edge of the group. The islands are volcanic in origin and La Palma is essentially a steep-sided volcanic cone. Although there is still some slight volcanic activity at the extreme south of the island, the site of the observatory on the northern lip of the great volcanic caldera, 2,400 meters above sea level, is free from any active vulcanism, apart from the minor tremors common in the islands. The British telescopes form the core of a new observatory, el Observatorio del Roque de Los Muchachos, named after a natural rock formation on the summit. Formally, the observatory is Spanish and belongs to the Instituto de Astrofisica de Canarias. The British telescopes belong to SERC. Underlying the dry legality, however, is an exciting and fruitful collaboration between European partners.

The main participating countries in the setting up of the observatory are Spain, the United Kingdom, Sweden and Denmark. The UK has, as scientific partners, two further countries: the Netherlands and the Republic of Ireland. The project in all aspects of its design and construction has been a good example of international collaboration. In addition the participants have signed an agreement which ensures that 5% of each telescope's time will be used specifically for observations which involve international coordinated attacks on major astronomical problems.

The Spanish are responsible for the infrastructure of the observatory — constructing the roads and a hostel for visiting astronomers, and providing electrical power and telephone lines to the observatory. In return, Spanish astronomers are entitled to use each telescope for 20% of the time. Swedish astronomers have already completed two telescopes, a 60 cm reflector and a solar telescope, and a group from the UK, Denmark and Space have constructed an automated transit circle, a specialized telescope for measuring star positions.

British participation in the Observatory is in the hands of SERC, which has given the task of building and managing the British telescopes to the Royal Greenwich Observatory. SERC has concluded an agreement with its Dutch counterpart, the ZWO (Netherlands Organization for the Advancement of Pure Research) for the joint operation, maintenance and development of the telescope installations. ZWO meets 20% of the costs of the telescopes and provides 20% of the staff. In return, Dutch astronomers will be able to take a 20% share of the UK observing time. The British share of the observing time will be used mainly by astronomers from British Universities and from the Royal Observatory, Edinburgh, and the Royal Greenwich Observatory.

The larger telescopes on La Palma will be reflectors, which use a mirror to gather light from stars and galaxies. The smallest UK telescope has a mirror 100 cm in diameter. It is designed to take fairly wide-angle photographs, 1.5° across, with negligible distortion. This allows astronomers to measure the positions of faint stars and galaxies relative to bright stars (with accurately-known positions) on the same photograph. The Republic of Ireland is contributing to this telescope's cost, in return for 27 nights observing per year.

The main UK telescope, for the moment, is the 2.5-meter Isaac Newton Telescope. This was originally located at Herstmonceux, and opened by Her Majesty the Queen in 1967. For the move to La Palma, the telescope has been re-engineered. Most important of the changes is the provision of a new high-quality mirror that will produce sharper images and do justice to the superb observing conditions on La Palma.

By the late 1980s, the INT will be joined by an even more powerful eye on the sky. The British telescope firm of NEI Grubb Parsons (at Newcastle-upon-Tyne), which constructed the first two reflectors, is now building the great 4.2-meter William Herschel Telescope, named after the famous astronomer who discovered the planet Uranus in 1781 and founded the science of observational cosmology. When completed in 1986, the William Herschel Telescope will be the world's third largest optical telescope with a single main mirror. It is expected that the exceptionally good observing site at La Palma, together with the use of the most modern light detectors, will give the William Herschel Telescope the edge over its larger rivals, the famous American Palomar 5-meter and the Russian 6-meter: it will be able to discern fainter objects and to see further out into space. The William Herschel Telescope will use an alt-azimuth mount, in which the telescope swings up and down about a horizontal axis supported on a cradle which swivels about a vertical axis. The new style of mounting simplifies the engineering. Although it requires more complex motions, these can be handled relatively easily by modern computers.

The Isaac Newton and William Herschel Telescopes will be fitted with some of the most sensitive light detectors yet developed. One of these, the Image Photon Counting System, consists of a special television camera looking at the output from an image intensifier, to make it more sensitive, and a computer, which sorts the noise from the picture and sharpens up the images. It is particularly useful for studying spectra (light from a star or galaxy spread out into its constituent wavelengths). For direct pictures of very small areas of the sky, astronomers will use a charge-coupled device. This is a large silicon chip which is sensitive to light. A CCD is about thirty times more sensitive than the best photographic emulsion, so exposure times can be cut from hours to just a few minutes.

Although there will always be astronomers and engineers at the Observatory, British astronomers will also be able to control and use the three major telescopes from the Royal Greenwich Observatory in Sussex — some 3,000 km away. Links by telephone line will allow

astronomers at Herstmonceux to move the telescopes and to view on TV screens what the telescope is seeing. A display of data (a spectrum, perhaps) that the telescope is obtaining can be seen, too. This innovation will save on astronomers' travel costs and time.

King Charles II founded the Royal Observatory in 1675 to assist navigation at sea. The original building, designed by Sir Christopher Wren, still stands in Greenwich Park in London. This century, the encroachment of London's lights made the skies of Greenwich too bright for most types of astronomical research and after WWII, the Royal Greenwich Observatory was re-established at Herstmonceux Castle, near Eastbourne in Sussex.

The Castle's grounds offered room for telescope domes and, in 1967, the telescopes moved from Greenwich were joined by the Isaac Newton Telescope, whose large aluminum dome forms a distinctive landmark for miles around. The telescope, with a main mirror 2.5 meters in diameter, was the largest British telescope ever built, and the largest in Europe. At the time it was conceived, in 1946, astronomers agreed that it should be sited in Britain. Here it would be conveniently situated for British astronomers and for engineering and maintenance purposes. Much research was then being directed toward the detailed study of relatively bright stars, for which a really dark sky is not essential.

By the time the Isaac Newton Telescope was in operation, however, two decades had passed and astronomers' interest had shifted to much fainter objects, very distant galaxies and the newly-discovered quasars. The atmosphere at Herstmonceux is not steady enough and the sky not sufficiently dark to study such objects, even when the sky is completely clear of clouds — which happens on average only 63 nights per year. In England, the telescope was less than half as efficient as it would have been at, say, one of the North American observatory sites. In the 1960s, with the advent of fast and relatively cheap air travel, it was thus possible to consider siting telescopes abroad where the skies were considerably better, and have the astronomers fly out to use them. After an approach by Australian astronomers, Britain joined in the construction of the 3.9-meter Anglo-Australian Telescope, which could view the southern sky. Plans evolved for a complementary overseas observatory to study the northern sky, with the Isaac Newton Telescope, suitably refurbished, as one of the major instruments. In 1969, British astronomers set up a committee to investigate the best possible site for the Northern Hemisphere Observatory, as the concept was then known.

It may not seem an impossible task to choose the best practicable site for a large optical observatory "somewhere in the Northern Hemisphere." However, in practice, there are remarkably few good candidates. The site must obviously have clear skies for a large proportion of the time, and for astronomers "clear" means not only absence of cloud but also of appreciable amounts of dust in the air. The images of stars must also be affected as little as possible by the Earth's atmosphere. Temperature fluctuations in the air broaden the image of a star into a blurred disk which is much larger than the sharp image produced by a large telescope. Furthermore, astronomers observing very faint astronomical objects must have a very dark sky, far away from man-made sources of illumination. A site survey undertaken in California several years ago, for example, found that an observatory had to be about 160 km away from a city with a population of 2,000,000 in order to obtain a dark enough sky.

Starting in 1971, the UK site survey team tested locations in Italy, the south of Spain, the Cape Verde Islands, Madeira, Hawaii, and Tenerife and La Palma in the Canary Islands — the last two with the encouragement of the Instituto de Astrofisica de Canarias, which runs an observatory on Tenerife. The team found the best sites to be the peaks of La Palma and Hawaii. The Mauna Kea site on Hawaii is, however, at an altitude of 4,200 meters, so high that it is difficult to work there and construction work extremely expensive — although the height is such an advantage for longer-wavelength observations that Britain has built the world's largest infrared telescope there and is now constructing a telescope for the slightly longer millimeter waves.

The peak of La Palma, on the edge of its volcanic caldera, is 2,400 meters high — elevated enough to be an excellent site, but not inconveniently high. It lies above the clouds for most of the time, and above the inversion layer which keeps down the bulk of the water vapour and dust in the lower atmosphere. The air above comes in a steady stream from over the Atlantic. The sea temperature alters much less between day and night than land temperatures, so the air above the observatory lacks most of the temperature variations which bend starlight and blur out the images of stars. Tests at the

The Observatory is situated on the edge of a large caldera.

Observatory show that, as a result, star images are less than 1 arc-second in size for 40% of the time. Another advantage of La Palma is that the island is not a major tourist resort; there are relatively few street lights and co-operation with local authorities can restrict their increase, so astronomers will be able to continue observing with really dark skies above them.

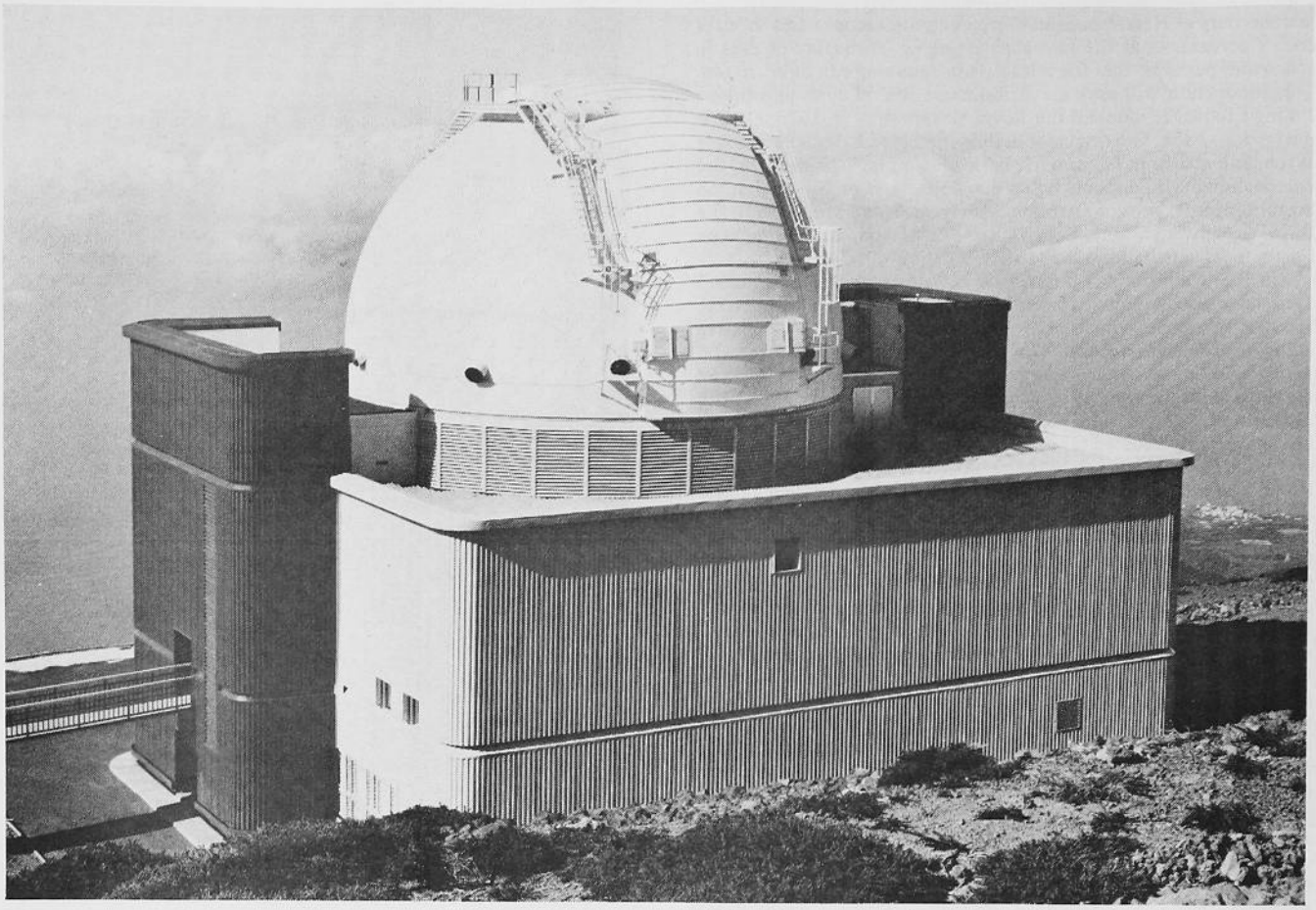
By the mid-1970s, other European countries were also interested in siting telescopes at an excellent site in the northern hemisphere. On May 26, 1979, Spain, the United Kingdom, Denmark, and Sweden signed an agreement to build an observatory and telescopes on La Palma, and el Observatorio del Roque de Los Muchachos formally came into being.

Since that agreement, the Netherlands and the Republic of Ireland have joined in the UK project. Dutch astronomers will provide some of the instruments for the three British telescopes, and meet their share of the costs in return for 20% of the UK observing time. The Irish have a small participation in the British one-meter telescope. A collaboration of Swedish, Norwegian, Danish and Finnish astronomers is testing for a site within the observatory for a 2.5-meter telescope, and groups from other European countries have expressed an interest. The observatory is the natural growth-point for British and European astronomy and will undoubtedly become even more important in the decades to come.

The One-Meter Telescope

The one-meter is a completely new telescope specially designed for astrometry, the accurate measurement of star positions. Its design means that it can photograph a wide field of view without introducing distortions. The secondary is unusual in having a spherical surface, and it reflects light back through a central hole in the main mirror, then through a two-lens corrector onto large photograhic plates.

The telescope is equipped with an automatic camera and can photograph a field 1.5° across. The individual star images are so little distorted that almost all the light from each star falls within a circle only 0.5 arc-second in diameter — the extent to which the Earth's



This building house the Isaac Newton Telescope at La Palma.

shifting atmosphere will blur the images anyway.

Wherever the telescope looks in the sky, this large field will include several bright stars whose positions are already accurately known, either from ground-based instruments like La Palma's Carlsberg Automatic Transit Circle or from the planned European astrometric satellite Hipparcos. Astronomers will thus be able to determine accurate positions for very faint objects on the same photograph, relative to these known star positions. Such research will help in identifying interesting objects found by radio and X-ray astronomers. Observations over a period of time will show very small changes in the relative positions of stars and galaxies. These will reveal how stars of different types are moving, relative to one another and to the Sun, and also tell astronomers how the system of stars in our rotating Galaxy is moving, because astronomers can compare them to the "fixed reference frame" provided by the positions of remote galaxies and quasars.

The telescope will also be used for photometry. For this, the spherical secondary mirror is replaced by a hyperboloidal secondary and the corrector lens removed. St. Andrews University has built a special spectrograph to use with the telescope in this mode, to measure the radial velocity of stars brighter than magnitude 10.

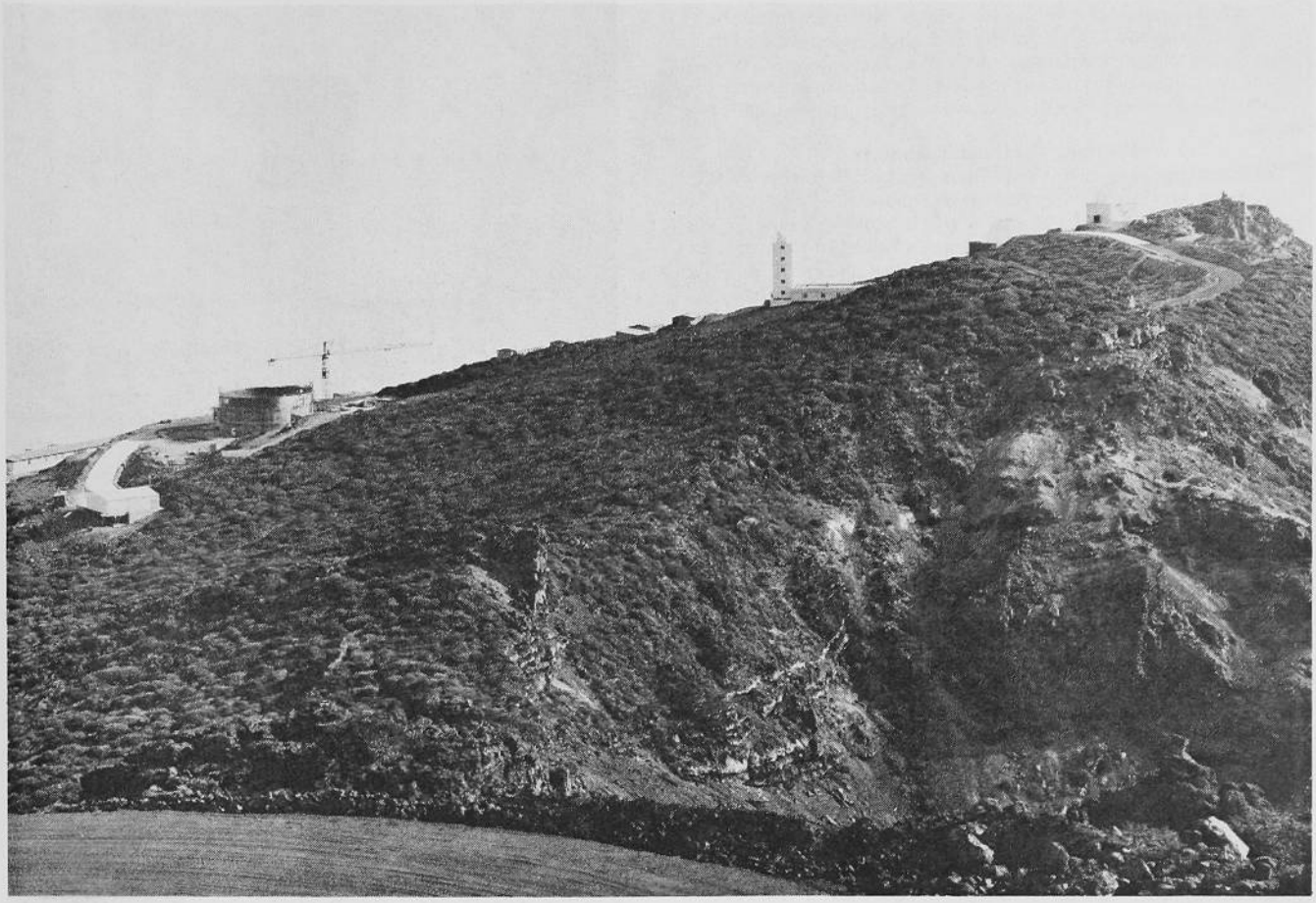
The Isaac Newton Telescope has a primary mirror 2.5 meters in diameter. The original "98-inch" mirror of borosilicate glass — cast as a test disk for the Palomar 5-meter telescope — would not have matched up to the superb conditions on La Palma. As a result, the telescope has been given a new, higher-quality mirror (which also happens to be a little larger, making it a "100-incher"). The new mirror is made of a glass-ceramic called Zerodur which expands and contracts very little when heated so that its shape remains almost constant during the temperature changes from day to night, thus introducing no noticeable distortions in the image. Its paraboloidal surface is one of the most accurate ever figured, producing extremely-crisp images: if the Earth's atmosphere did not produce blurring, it would concentrate 99% of the light from a star into a circle only 0.4 arc-second in diameter.

The other major change necessitated by the move from Herstmonceux to La Palma is a result of the change in latitude from 51°N to 28°N. The Isaac Newton Telescope has an equatorial mounting, where one axis — the polar axis — points to the north celestial pole. The latitude change means that the telescope mounting must now be tipped up more. The new angle would mean that the big disk which forms part of the mounting would have prevented the telescope from tipping up far enough to view the southern part of the sky visible from La Palma. A section of this disk has thus been cut away. From its new site, the Isaac Newton Telescope declination limit has extended from −15° to −32°.

Although the telescope has basically the same mounting, the drives on the two axes have been modified to match modern standards for servo-control. This means that the computer control system can feed in small corrections to the telescope's motion to correct for minor changes during observing, in particular the slight bending of the telescope due to its own weight as its angle changes, and the small change in the apparent position of a star near the horizon caused by refraction in the atmosphere.

The main mirror (f/2.9) brings light to prime focus 7 meters up the framework tube. Here the light passes through a three-lens corrector which ensures that the star images are undistorted over a fairly wide field of view, at 40 arc-minutes across, larger than the apparent diameter of the Moon. In the refurbished telescope, astronomers will not have to sit in a cramped "cage" at the prime focus, as was previously necessary to guide the telescope and change the photographic plates. The telescope will now be guided automatically, and an automatic plate and filter changer will allow the astronomer in the control room to replace the plates and select a suitable color filter to go in front. Photographic emulsions are, however, rather insensitive to light, and the main detector at the prime focus will therefore be a CCD and light-sensitive silicon chip.

Most astronomers, however, will use the INT in its Cassegrain configuration. At this more accessible focus, the Isaac Newton Telescope carries a new spectrograph with two cameras to record the spectrum at different scales, using the Image Photon Counting System discussed earlier. While the spectrograph is recording the spectrum of light from one particular star or galaxy, a separate TV

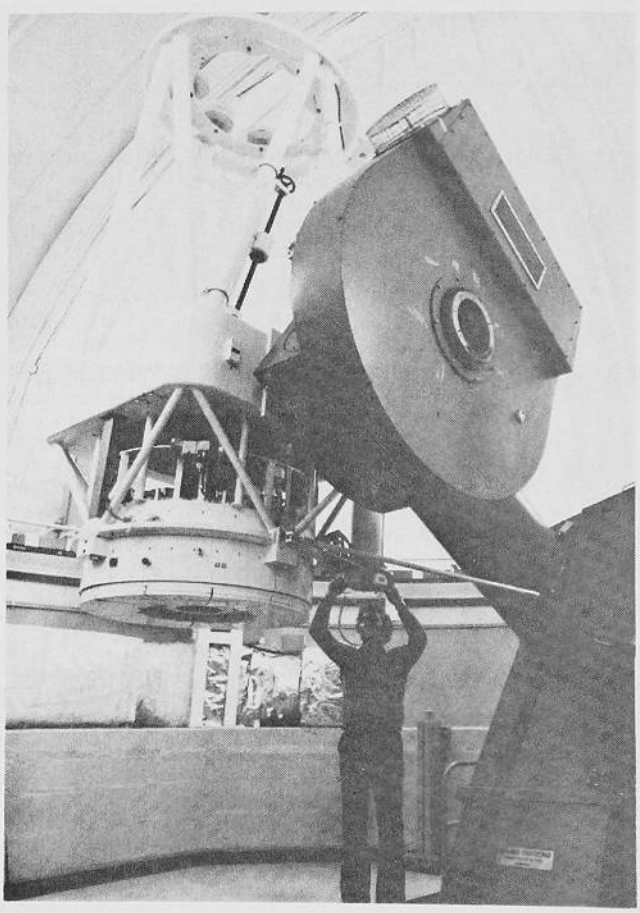


The observatory site: the WHT is at left; the INT and 1-m at right.

camera sends a picture of the whole field of view back to the control room. This enables the astronomer to check that he has found the right object initially and shows at which part of an extended object — a nebula or galaxy — the spectrograph is looking. Even with the telescope's sophisticated mounting, it is important to check that the INT is following the apparent motion of the stars precisely. Older telescopes required an astronomer to check continuously, watching a star through a guide telescope attached to the main telescope. The INT has electronic autoguiders to ensure accurate tracing automatically.

New detectors now being built will keep the Isaac Newton Telescope at the forefront of world research. A special faint-object spectrograph with a CCD camera and the minimum practicable number of light-absorbing lenses and mirrors will take spectra of objects two or three times fainter than the limit of the present spectrograph, although not in such detail. Dutch astronomers are developing a photometer to measure a star's brightness simultaneously at six wavelengths. Another British imaging spectrograph, called TAURUS, will be taken from the Anglo-Australian Telescope in Australia to be used on the Isaac Newton Telescope. TAURUS can show the motions of gas in different parts of a nebula or galaxy in open view. The telescope will also have a Coude focus, where light is taken by a different secondary mirror and five extra flat mirrors (or by a long fibre-optic cable) to an adjacent room where heavy spectrographs can be sited to provide a detailed examination of the spectra of the brighter stars.

The Isaac Newton Telescope is housed in a dome on top of a three-story building that forms the headquarters for the British telescopes at the Observatory. A large vacuum tank on the ground floor is used to evaporate the thin film of reflecting aluminum onto the surfaces of the Isaac Newton Telescope's mirrors; it will also aluminize the smaller mirrors of the adjacent one-meter telescope. The building



The 1-meter telescope is now installed in its dome.

has mechanical and engineering workshops, electronics workshops for constructing and testing the electronic light detectors, and dark rooms for developing the photographic plates. There are special rooms for the computers which drive the telescopes and which analyze the results. The astronomers will also have a library, canteen, and rest-rooms.

William Herschel Telescope

When completed in 1986, the William Herschel Telescope (WHT) will be the world's third-largest single-mirror telescope. With a primary mirror 4.2-meters across, it will be exceeded only by the Soviet 6-meter and the American 5-meter on Palomar Mountain, and will be similar in light collecting power to the American Multiple Mirror Telescope in Arizona, which has six 1.8-meter mirrors.

The primary mirror will be housed at the bottom of a conventional telescope tube of steel struts. But the telescope breaks with tradition in carrying the tube on an alt-azimuth mounting, rather than an equatorial mounting used for the Isaac Newton Telescope and most other large telescopes. In the alt-azimuth form, the telescope can rotate about a horizontal axis, supported on bearings on top of a Y-shaped frame which can turn around its vertical axis. This simple combination of horizontal and vertical axes makes for a less massive mount and easier enginering, but requires the telescope to swing about both axes — and at continuously-changing rates — as it tracks the apparent motion of a star across the sky. All modern large telescopes, however, incorporate a computer in the control system, and the William Herschel Telescope's computer will be able to handle the drive about the two axes with no difficulty.

The telescope's large mirror focuses light to the prime focus, 10-meters up the tube, where a correcting lens system ensures that the field of view is sharply in focus over a region 42 arc-minutes in diameter. Alternatively, a secondary mirror here can reflect light back down the tube to the Cassegrain focus just behind the mirror itself.

The WHT has a third mirror which gives three more focus positions. The telescope structure is supported by two bearings attached to the tube's central frame, which is an open square. (From this square frame, support struts go down to support the mirror cell, and up to hold the prime focus assembly.) The third mirror is located in the center of the frame and is angled at 45° so that it diverts sideways the beam of light coming down from the secondary. After that reflection, the light comes to a focus just beyond the sides of the frame. The side is chosen by turning the mirror. In addition, one of the sides without bearings has been pierced to allow light through to a focal point called the broken Cassegrain focus.

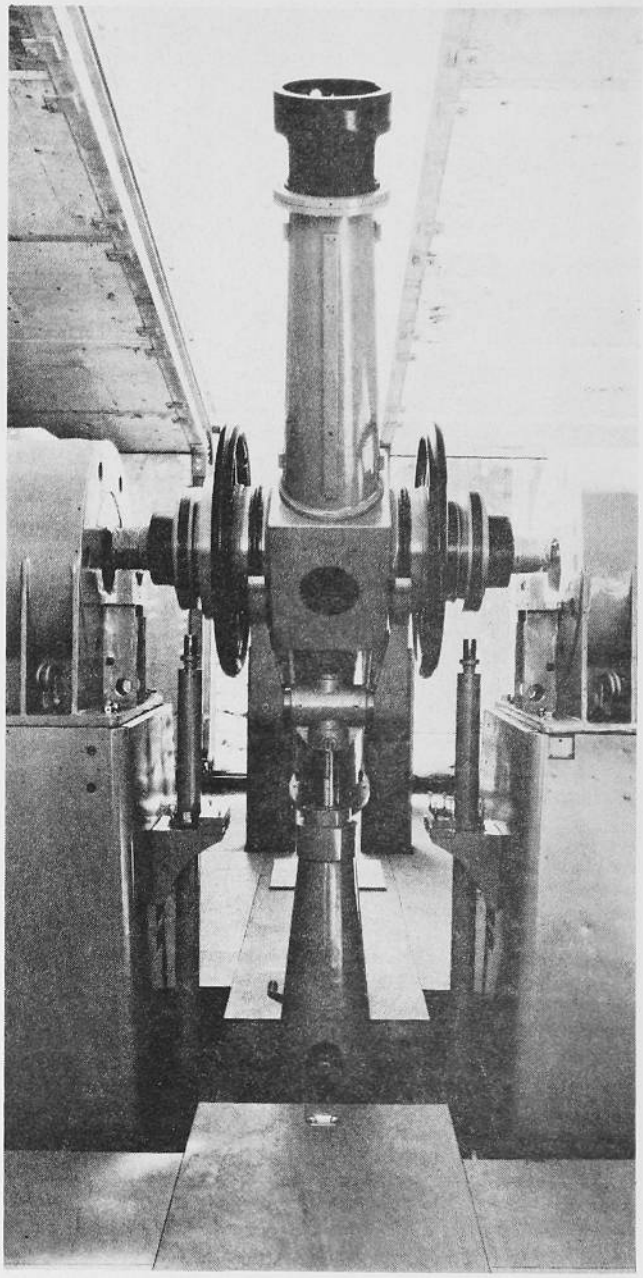
The bearings themselves are pierced longitudinally so that light can pass through from the third mirror to a focus just beyond the bearings. The two Nasmyth foci are at the tops of the fork mounting, and here astronomers can place heavy equipment for analyzing and detecting the light without its weight distorting the telescope's shape.

This telescope will be considerably larger than the Isaac Newton Telescope, but its building will, in fact, be smaller. Although the building will contain a vacuum tank for coating the large mirror with aluminum, it will not duplicate the workshops, library and rest-rooms that are provided in the INT building. Moreover, the alt-azimuth design of the mounting allows the dome to be built snugly and economically around the telescope.

Carlsberg Automatic Transit Circle

This instrument is the result of international collaboration between Danish, British and Spanish astronomers. It is an 18cm reflecting telescope specially designed and mounted to measure extremely accurately the positions of bright stars. The telescope, manufactured by the British firm NEI Grubb Parsons, has been carrying out a series of test observations at the Copenhagen University Observatory, Denmark. It swings north-south along the meridian line and measures the positions of stars electronically as they cross this imaginary line nightly. As its name suggests, it was funded by a science foundation set up by the Carlsberg Brewery Company. The program of observations on La Palma involves the Royal Greenwich Observatory and the Instituto y Observatorio de Marina (San Fernando) as well as Copenhagen University Observatory.

The automatic transit circle is now computer-controlled, so it can scan up and down the meridian automatically. The instrument will be able to measure the positions of a thousand stars in a single night, each to a high accuracy of 0.2 arc-second. By averaging several measurements on different nights, the error for each star can be reduced to 0.1 arc-second, or less. The conditions on La Palma should enable the telescope to obtain positions for stars fainter than currently



The Carlsberg Automatic Transit circle being re-erected at La Palma.

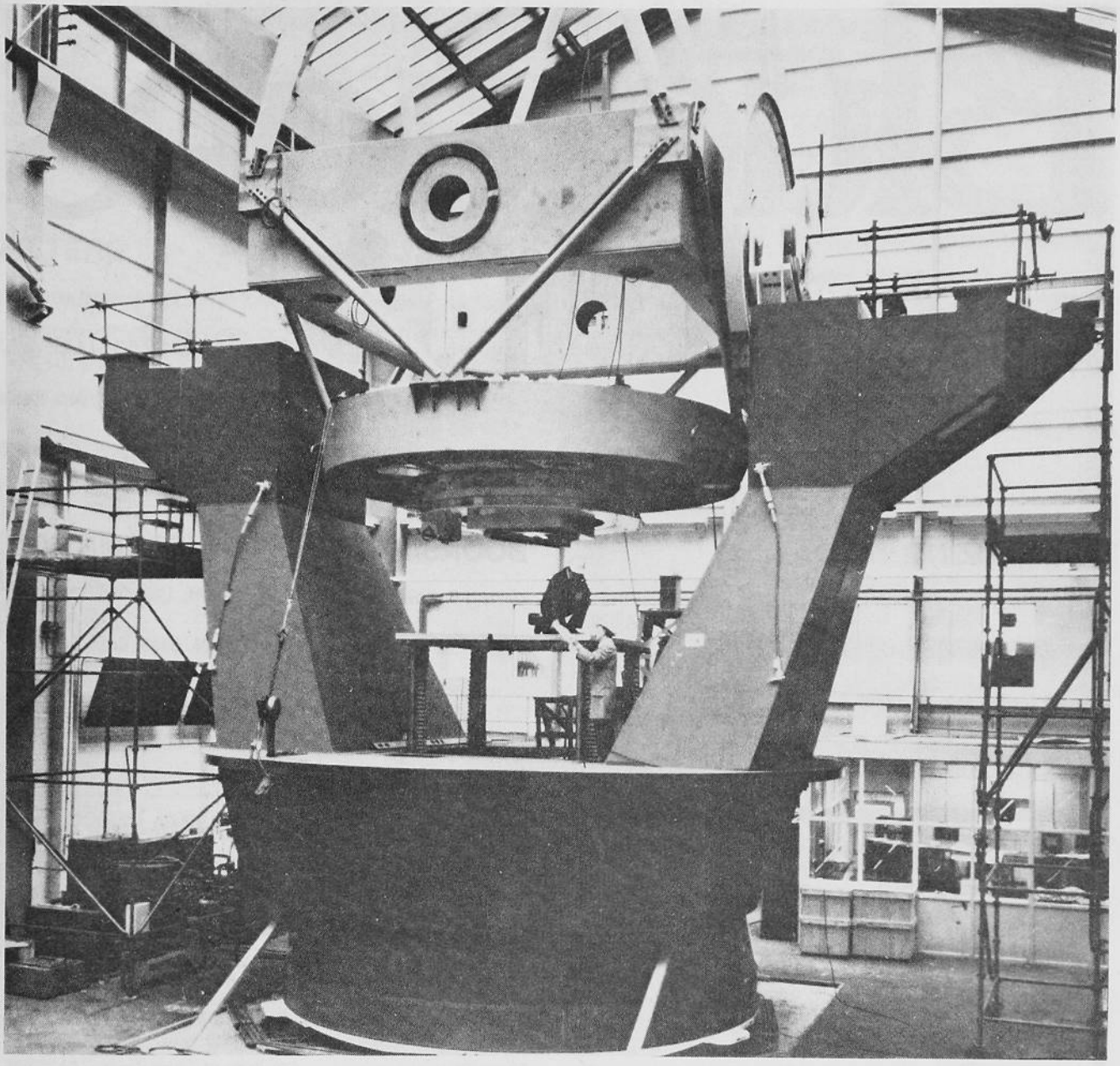
observed with this instrument, and produce about 200,000 observations per year — about five times the previous rate.

In total, the Carlsberg Automatic Transit Circle will be able to measure the positions on 500,000 of the brightest stars visible from La Palma. When combined with earlier measurements, the positions will reveal the small movements of the stars (their "proper motions") from which astronomers deduce how our Galaxy is rotating.

Remote Operation

The British telescopes on La Palma will be the first to be set up so that they can be remotely controlled from the U.K. Astronomers will be able to operate the telescopes from the Royal Greenwich Observatory in Sussex, over ordinary telephone lines, rather than incur the expense and suffer the inconvenience of traveling to the Canary Islands.

Modern telescopes no longer need an astronomer at the eyepiece. Data are usually collected by electronic light detectors and fed through cables to an adjoining control room. The astronomer in the control room not only has a display of the data coming in, he can also see the telescope's field of view on a television screen. He can send commands to the telescope's drive computer if he wants to move



Work continues on the WHT at the NEI Parsons works.

the telescope, or to another computer to control the telescope's instrumentation. Remote control from the United Kingdom is thus really just a matter of "stretching" the cable between telescope and control room from a few meters to a few thousand kilometers.

At present, British astronomers fly to telescopes under the clear skies of places like Australia, South Africa, or Hawaii to make their observations. In recent years, however, the cost of communications has been dropping to levels where it costs no more to hire a telephone line than to send an astronomer overseas for a few nights' observations. Astronomers have also mastered the techniques of remote control as a result of using unmanned satellite observatories.

At present, with all its major optical and infrared telescopes abroad, the UK leads the world in the remote control of telescopes. In September 1982, the Royal Observatory, Endinburgh, remotely operated the UK Infrared Telescope on Hawaii, and obtained spectra of infrared stars. Within a few weeks, the Royal Greenwich Observatory, in preparation for remote operation of the La Palma telescopes, operated the 2.1-meter telescope at Kitt Peak in Arizona. Television screens at the Observatory showed for the first time the view through a telescope on another continent.

The links with La Palma will initially be through five telephone lines each carrying 9600 bits of information per second, and will also provide a voice link to staff at the telescope, a TV display of the telescope's view, and a simplified version of the data it is obtaining. Since the lines cannot carry all the data a large telescope gathers, these will be stored on magnetic tape and can be flown back to the UK the next day — as quickly as a researcher could carry them back if he visited the telescope to observe in person. Remote operation will open up new ways of observing so astronomers in Britain can choose to make particular types of observations when the weather on La Palma is best suited, instead of each astronomer traveling out on a pre-arranged schedule and taking pot luck with the seeing.

Some astronomers will still have to travel to set up and test new equipment and — for young researchers in particular — to become familiar with the operation of a large telescope. There will be permanent staff on La Palma, both astronomers and technicians, to ensure that the complex equipment is working perfectly and to respond to any problems that may crop up. But remote control will save significant amounts of time and money in the operation of the UK's new instruments, as well as leading to new, flexible and efficient means for astronomical research.

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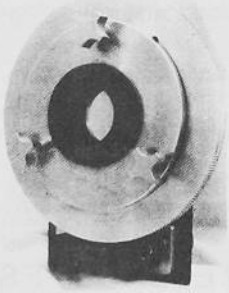

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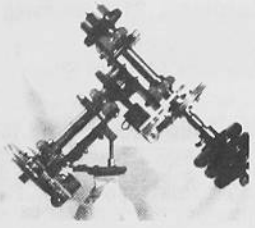

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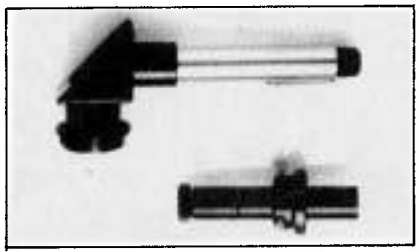

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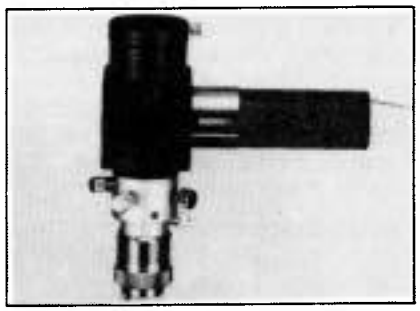

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Microcomputers in Astronomy, ed. by Russell M. Genet. Thirty papers presented at the Fourth Fairborn Symposium detail the present state-of-the-art in applying microcomputers to automatic telescope control. An absolute must for everyone interested in controlling telescopes or photoelectric photometers by computer. 253 pages, paperback, **$23.95.**

Software for Photometric Astronomy, by Silvano Ghedini. You don't have to write your own software — Ghedini has already done it. Written in HP BASIC, the programs begin with air mass and extinction corrections, then leap to determining time of minimum light and period analysis of variables. 221 pages, paperback, **$27.50.**

Advances in Photoelectric Photometry, Vol. 1, ed. by Russell M. Genet and Robert C. Wolpert. Nineteen papers on the latest achievements in photometry including tips on how to do photometry from poor sites, building fully automated telescopes and descriptions of typical productive amateur-run observatories. A must for the up-to-date amateur. 240 pages, paperback. **$23.95.**

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LUMICON

HIGH PERFORMANCE TELESCOPE PARTS

ASTROPHOTO OF THE MONTH

Crab Nebula M-1 in Taurus. The Crab Nebula is seen best visually with a LUMICON DEEP-SKY Filter. Photo by David Healy using a LUMICON Giant EASY-GUIDER and LUMICON hypered 2415 film. 33 min. exposure, Celestron-14 at f/6.

LUMICON® FILTERS STOP LIGHT POLLUTION

The **LUMICON DEEP-SKY Filter**™ improves both visual and photographic contrast on all deep-sky objects, including galaxies. The **LUMICON UHC Filter**™ is for viewing only and yields the highest contrast for planetary and emission nebulae of any filter available today.

Filter Type	UHC	Deep-Sky
For 0.965" eyepieces	—	$49.95
For 1¼" eyepieces	$79.50	$59.50
48mm for 2" eyepieces	$119.50	$99.50
For 2" eyepieces & photography		$99.50
Set, 1¼" UHC & Deep-Sky Filters		$119.50
Selected premium filters		add $20

H-Beta Filter, 1¼" . . . . $69 48mm $119

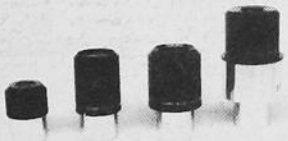
H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$29.95	$25.00
52, 55, 58, 62mm	$39.95	$29.95
67, 72, 77mm	$46.95	$39.95
82mm	$49.95	

Hypered 2415 film, 36 exp . . . $9.95 . . . 3/$27

TELE VUE™ EYEPIECES USE THE BEST!!



Plossl, Wide-Field, Nagler Eyepieces

Tele Vue Plossl eyepieces have a sharp 50° apparent field-of-view. The Wide-Field eyepieces have a 65° field-of-view and are sharper than Erfle and Konig Eyepieces. The revolutionary Nagler eyepieces are sharp clear to the edge of a giant 82° field-of-view. **The eyepiece is half the telescope — use the best!**

7.4, 10.4, 13, 17, 21, 26mm Plossl(50°) . . . $65
2½X Tele Vue Barlow Lens $65
32mm Plossl, widest true field in 1¼" . . $80
55mm 2" Plossl, widest possible field . $160
19mm Wide-Field, 1¼" eyepiece (65°) . $110
24mm Wide-Field, "superb" (65°) $125
32mm Wide-Field, 2" eyepiece (65°) . . . $195
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4.8mm Nagler, 82° field $125
9mm Nagler, 82° field, "the best" $195
13mm Nagler, 82° field, 1¼" or 2" $220
(apparent field of view in parenthesis)

SUPER-FINDER™

The LUMICON SUPER-FINDER is both a compact Rich-Field Telescope and a magnificent "Super-Finder". It has a fully coated 80mm achromatic lens and 300mm focal length. The Deluxe SUPER-FINDER has a superb 500mm f/6 air-spaced lens.

10X80mm SUPER-FINDER $149.95
1¼" SUPER-FINDER w/o eyepiece . $129.50
1¼" Right-angle SUPER-FINDER* . $129.50
2" SUPER-FINDER w/ 1¼" adapter . $139.50
2" Right-angle SUPER-FINDER* . . . $169.50
1¼" DELUXE SUPER-FINDER* $199.50
2"/1¼" DELUXE SUPER-FINDER* . $249.50
**Requires a 1¼" or 2" star diagonal*

1¼" star diagonal, 30mm aperture . . $26.95
2" LUMICON mirror-type star diagonal, threaded for 48mm filters . . . . . **add $89.50**
Mounting rings, 3-5/8" I.D **$16.95/pair**
Mounting adapter for C-8, Meade etc . . . $35

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 13" & 3.1" enhanced silver diagonals.

The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed pyrex flat to 1/8 wave.

Diagonal Size	Price
1.32" Minor axis	$29.95
1.52" Minor axis	$34.50
1.83" Minor axis	$39.50
2.14" Minor axis	$47.50
2.60" Minor axis	$59.50
3.10" Minor axis	$79.50
4.25" Minor axis	$129.50

ENHANCED SILVER STAR DIAGONALS

LUMICON 2" Star diagonal with enhanced silver mirror.

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

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LOW PROFILE NON-ROTATING HELICAL FOCUSER

LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a SUPER-FINDER. LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2" I.d. eyepiece holder. It has a vertical travel of 1¼" and a very low profile only 1¼" high. It is CNC machined, black anodized, and a perfect match to a LUMICON Newtonian EASY-GUIDER.

Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 20" OD, SUPER-FINDER base plate.

LUMICON Deluxe Helical Focuser . . **$69.50**
3 handles (see photo) **$12.95**
Helical focuser with 3 handles **$79.95**
2"/1¼" adapter w/48mm filter threads **$16.95**
2" LUMICON EASY-GUIDER **$139.50**

NEW! GIANT LUMICON® DEEP-SKY FILTERS

48mm, 58mm, 72mm DEEP-SKY Filters

LUMICON now offers its high performance **DEEP-SKY Filters** in larger sizes. They allow **both** color & B&W photography with larger telescopes. Light pollution is reduced 3-6 fold, stellar images improve and emission nebulae have increased red contrast.

DEEP-SKY FILTER	PRICE
48mm (46, 49, 52mm add $6.95)	**$99.50**
58mm (55, 62mm add $6.95)	**$129.50**
72mm (67, 77mm $6.95)	**$149.50**

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FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†Patent Pending

MODEL 100 HYPER-KIT for 35mm film, rolled-up. *Takes longer,* but it easy to use. Not recommended for 2415 . . . . . **$225.00**

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$275.00**

MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$299.50**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller . . . **$525.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump **$265.00**

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All **LUMICON EASY-GUIDER**™ off-axis guiders† have both radial and 360° rotational adjustments for 5X ealser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*

†Patent Pending

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$139.50**
3X Relay Diagonal [See Photo] **$59.50**
Illuminated reticle eyepiece system . **$59.50**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$199.50**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$359.50**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER [SAVE $20] . . . . . **add $79.95**

WHAT DO YOU NEED?

1. Hypersensitized Film. Use a LUMICON HYPER-KIT to insure a fresh supply, or use film pre-sensitized by LUMICON.
2. LED Illuminated reticle eyepiece system and battery pack, dual crosslines . . . **$59.50**
3. Telescope with good drive. (See above)
4. Piggyback adapter (state telescope type)...**$25** Deluxe adjustable **$39.50**
200mm f/3.5 multicoated lens **$99.95**
5. Filtration is essential for all lenses. Use hypered 2415 and the H-Alpha Pass Filter. For III a-J or color, use the Minus Violet Filter or the LUMICON DEEP-SKY Filter.
6. Off-axis guider is **essential** for consistently good prime-focus astrophotography.
7. Dual-axis drive corrector and electric declination (state telescope type) **$259**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. For fine grain B&W film use 2415. The fastest color films are Fujichrome 400 for slides and Kodak VR1000 for prints. Use VR1000 for galaxies and Fujichrome 400 for nebulae.

Film Type (35mm unless marked)	Exposures	Price
2415, Ultra-fine B&W, red sens	36	$9.95
Ektachrome 200 prof. 5036	20	$9.95
Fujichrome 400, "Excellent"	20	$12.95
VR1000, fastest of all, color negs	12	$12.95
5072, color slides from negs	36	$6.95
D-19 B&W Developer, 1 gal.		$5.95

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PRESENTS

THE

1984 ASTROFEST

Astrofest, the annual midwest gathering of telescope makers and amateur astronomers from all over the country, will be held September 21, 22, and 23, 1984, at Camp Shaw-waw-nas-see near Kankakee, Illinois. Hosted by the Chicago Astronomical Society, **Astrofest** has attracted participants from nine states and Canada.

Astrofest is geared to telescope makers as well as deep-sky, lunar, solar, and planetary observers. Daytime events include telescope judging, paper sessions, speakers, workshops conducted by professionals, and the Astro-Flea Market. All night star parties run both Friday and Saturday nights at this relatively dark site.

Featured this year is a personal tour of Mars by ALPO Mars recorder Charles F. Capen, formerly of JPL and Lowell Observatory, whose talk will be "Martian Quest." He will also conduct a workshop on planetary and comet observing. In addition, Richard Berry will conduct a workshop on astrophotography, including a survey of the current state of the field. David Eicher, founder of DEEP SKY Magazine, will conduct a workshop on deep sky observing techniques.

Supplementing these three workshops are papers presented by advanced amateur astronomers on topics stretching across the universe of telescope making and observing. Start planning now to present your own paper at **Astrofest**, telling other amateur astronomers about the projects you have been working on recently; the title and a synopsis will be required by August 30th.

Telescopes made by amateur astronomers from all over the country will be on display and will be examined by a team of expert judges on the basis of quality, usability, inventiveness, and performance. As in the past, the telescope display is the centerpiece of **Astrofest**, demonstrating the practical side of the theory presented in the workshops and paper sessions. If your telescope is homemade, or incorporates unique features into a commercial telescope, **Astrofest** is the place for it to be in September.

A number of commercial telescope manufacturers and distributors will be on hand so you can see their equipment first-hand and even field test it, weather permitting. Many commercial telescopes are of excellent quality, and many attendees will be bringing their own commercially-made telescopes for you to compare and contrast.

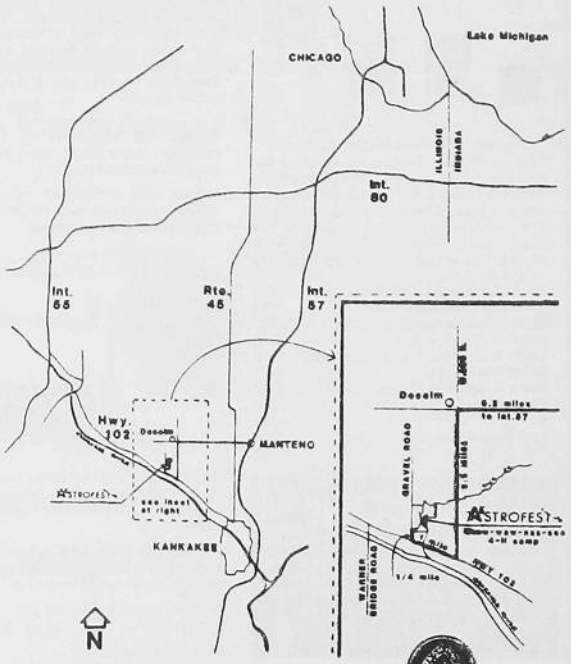
Astrofest is being held for the third year at 4-H Camp Shaw-waw-nas-see. Camp Shaw is situated on 130 acres of pleasantly balanced park-like and wooded terrain. The camp facilities include rustic dormitory-style cabins, toilets, a 300-seat dining hall with fireplace and plenty of room for observing and camping.

The camp is bisected by Rock Creek, which flows through a scenic limestone canyon with sheer rock walls, unique in northern Illinois. A waterfall and rapids make hiking around the trails at Camp Shaw-waw-nas-see a lovely and exciting experience.

Catered meals will be available to the first 160 people who pre-register for lunch and dinner on Saturday. Friday dinner and Sunday breakfast are not provided. A snack of coffee and donuts will be provided early Saturday morning.

Sleeping space in the cabins is available on a first-registered, first-served basis, so write for your 1984 **Astrofest** brochure now. Send your name and address to:

Astrofest
Box 596-T
Tinley Park, IL 60477



LOCATION MAP

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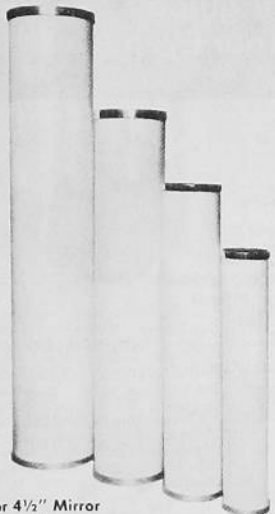

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Absolutely the very best telescope tubes available. Developed and perfected in 1954 by Parks, our fiberglass telescope tubes are *simply unique in all the world.* We invite you to examine some of their unsurpassed qualities:

- ★ Virtually Indestructible
- ★ Extremely Low Thermal Conductivity
- ★ Resists Moisture and Corrosion
- ★ Does Not Chip or Peel
- ★ Exterior is White Smooth Glass-like Finish, and Flat Black Interior
- ★ Never Needs Painting, Their Color is an Integral Part of the Manufacturing Process
- ★ Easily Sawed, Drilled or Riveted by using Commonly available tools
- ★ Time Tested and Fully Guaranteed

For 4½" Mirror

5" x 48" ..... $ 39.00

For 6" Mirrors

7" ID x 31" to 52" $ 52.00
7" ID x 53" to 60" $ 56.00
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For 8" Mirror

9⅜" ID x 24" to 37½" $ 56.00
9⅜" ID x 38" to 55" $ 68.00
9⅜" ID x 56" to 60" $ 72.00
9⅜" ID x 61" to 75" $ 80.00
Anodized Aluminum end rings/pair $ 17.00

For 10" Mirrors

11⅞" ID x 40" to 48" $ 99.00
11⅞" ID x 49" to 62" $116.00
11⅞" ID x 63" to 72" $132.00
Anodized Aluminum end rings/pair $ 24.00

For 12½" or 14¼" Mirror

15⅞" ID x 48" to 59" $148.00
15⅞" ID x 60" to 69" $160.00
15⅞" ID x 70" to 79" $170.00
15⅞" ID x 80" to 100" $190.00
Anodized Aluminum end rings/pair $ 28.00

For16" Mirror

18" ID x 48" to 60" $160.00
18" ID x 61" to 90" $240.00
18" ID x 91" to 120" $280.00

Other Sizes Available Upon Request

Astronomical Mirrors

Our Mirrors are made from a premium quality fine annealed blank of low expansion type Pyrex #7740 with a 1 6 ratio of thickness to diameter. The optical surface is extremely smooth – no dog bisquiting. Exceptionally clean. Focal lengths ±3%. All mirrors are smooth parabolic figures without any zones or breaks. Each disk exhibits a good diffraction ring, no turned edges or edge zones. Each mirror exhibits straight Ronchi bands edge to edge under the sensitive double pass auto-collimation test. Corrected to better ±1/25th wave. Free of astigmatism. All mirrors Aluminized with silicon monoxide and Guaranteed to be of the highest quality available anywhere.

6" F/6 or F/8 $ 85.00
8" F/6 or F/7 $125.00
10" F/5, F/6 or F/7 $250.00
12½" F/5 or F/6 $395.00

Elliptical Diagonal Flats

Made of fine annealed Pyrex ±1/25th wave, aluminized. Excellent Quality

1.330" $15.00 1.830" $22.00 2.610" $35.00
1.550" $20.00 2.140" $28.00 3.100" $45.00

PARKS Giant Binoculars

UV-coated objectives, fully coated eyepieces and prisms. Fine quality, case included.
11x80, 15x80, 20x80, 30x80, $199.00 each — Tripod Adapter, $12.00

PARKS Spider/diagonal holders for:

7" ID tube w/1.52" holder, $25.00 — 9⅜" ID tube w/1.83" holder, $28.00
11⅞" ID tube w/2.14" holder, $30.00 — 15⅞" ID tube 2/2.60" holder, $35.00

PARKS Mounting Rings (Clamp Style, shown above)

Rolled steel rings for mounting tube assembly to saddle. Has flat base, will adapt to tube sizes other than our own. They come painted and felt lined, ready for use. For

7" ID tube, a pair $50.00 9⅜" ID tube, a pair $60.00
11⅞" ID tube, a pair $70.00 15⅞" ID tube, a pair $80.00

PARKS Rotating Rings

Sturdy, machined aluminum fully rotating rings for Parks tubes. Ready to use. For

9¾" O.D. tube, a pair $175.00 12¼" O.D. tube, a pair $275.00
16½" O.D. tube, a pair $325.00 18½"O.D. tube, a pair $400.00

PARKS Mirror Cells

Cast aluminum mirror cells. Quality construction throughout. For

6" cell (for 7" to 7 1/16" I.D. tube), $20.00 8" cell (for 9⅜" I.D. tube), $28.00
10" cell (for 11⅞" I.D. tube), $35.00 12½" cell (for 15⅞" I.D. tube), $45.00

PARKS Focusers

Smooth rack-and-pinion style with positive stops at each end of travel. Adjusting system for tension. Highest quality.

1¼" – $29.00 2" – $45.00

Counterweights

Cast iron weights are 10 lbs. each, painted and are available in 1" or 1½" bore. Locking set screw holds it where you want it. $25.00

Setting Circles

Aluminum die cast, 6" diameter, 11/16" face widths. 1" and 1½" Bore. Per pair $40.00

Illuminated Reticle (New, Compact-State-of-the-Art)

Kellner 12mm with battery pack, 1¼" Double-crossline reticle, remote brightness control. Focusable reticle. Cell Batteries included. Power cord 4'5". $49.00

Kellners Eyepieces

Performance plus a moderate price. Fully coated. Standard 1¼" and 2" threaded to accept filters. Focal lengths:
1¼", 6mm, 12mm, 25mm, 40mm. $22.00
2", 50mm, 60mm. $59.00

PARKS Ortho-scopics

We offer a truly excellent 4-element design Orthoscopic eyepiece that gives high resolution and color correction. Fully coated for maximum light transmission. Sharp 45° apparent field of view. Standard 1¼" threaded barrels.

f.l. 5mm, 6mm, 12.5mm, 25mm. $33.00

PARKS Erfles

Multi-coated, top quality eyepieces 65° designed for breathtaking wide field observing with maximum eye relief.

1¼" - 20mm, 32mm – $45.00 2" - 32mm – $85.00

PARKS Plossls

Exquisite optics in a true Plossl design, ultra high contrast parfocal, multi-coated, wide field with exceptional eye relief. 6mm, 9mm, 12.5mm, 18mm, 25mm, $49.00 40mm, $59.00

PARKS Barlows

Full 26mm aperture, doubles the power of any eyepiece while maintaining excellent image quality. Designed to yield professional performance. $29.00

PARKS Photo-Visual Color Filters

Excellent high quality photo-visual color filters made of top quality Hoya glass. Spectrum is homogenized as in 35mm camera filters, magnesium flourite coated for maximum light transmission. Threaded on both ends for use with 1¼" O.D. eypiece and to use filters piggyback.

#8 light yellow, #11 yellow green, #12 yellow, #15 dark yellow, #21 orange, #23A light red, #25 red, #56 green, #80A medium blue, #82A light blue, #29 dark red, #38A dark blue, #58 dark green, Polarizer 30% $10.00

PARKS Nebular Filter (LPB)

Light pollution reduction filter for blocking mercury and sodium light pollution. Brings the country skies to your backyard. Threads into 1¼" eyepiece. $49.00

PARKS Viewfinders

An excellent large aperture finder. Features coated achromatic optics, crosshair reticle helical type focusing for precise images. Not of the hit and miss push/pull type.

8x50mm Straight thru model $45.00
8x50mm Right angle model $49.00
Mounting brackets $12.00
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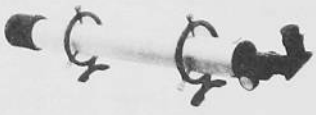
6x30mm 7" Right angle model w/bracket $35.00

PARKS 2.4" Refractor Guidescope

For your photographic applications we offer a top quality 2.4" refractor guidescope (D=60mm, F=700mm). Fully-coated objective lens, rack-and-pinion focusing, star diagonal prism, and H 35mm eyepiece. $69.00
Two ring mounting brackets $12.00/pair



PARKS Heavy-Duty Equatorial Mount

PARKS heavy-duty equatorial mount shown above with 10" tube assembly. The massive equatorial head is cast of virgin aluminum and machined precisely to exacting tolerances. Timpkin tapered bearings mounted on polar shaft assure trouble-free performance. Steel pier of 6½" diameter with heavy wall gives rigidity necessary for photographic applications. Steel shafts are 1½" diameter. Three heavy-duty steel pier legs and two 10lb counterweights included. Saddle plate adaptable to any size tube or can be used with multiple tube sizes. Complete as described, $450.00

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Simi Valley, California 93065
Phone: (805) 522-6722

TO ORDER: Send your request with a Check or Money Order in the amount listed above. Calif. residents add 6% Sales Tax. Tubes and Equatorial Mounts, shipped freight collect. We pay shipping and insurance on all other merchandise in Continental U.S. C.O.D. and Credit Card holders call Toll Free (800) 235-3344 (order line only), in California call (800) 847-2673. For information call (805) 522-6722.
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Tele Vue™

Send for free guide: "Choosing Your Eyepieces"

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PLÖSSL EYEPIECES
"SHARPEST I'VE EVER USED"

"Used with my 12" f/7, the Plössls deliver crisp images of the planets. I have the distinct impression that the eyepiece adds no optical errors to the image I'm viewing, and that I am seeing everything the mirror can deliver. This is an impression I've never had with any other eyepiece. Tele Vue Plössls are the sharpest I've ever used." — From review in August '81 "Astronomy"

New 4 element design improves performance of any telescope. Exceptional contrast and resolution over the entire 50° field, even with fast Dobsonians. Ideal for astrophotography too. Multi-coated. Chromed barrels threaded for filters.

55mm (2" barrel),
40mm & 32mm (1¼" barrel)
have widest fields possible for low power viewing. 7.4mm to 32mm models parfocal. 2.5x Barlow is a matched parfocal design. Actually improves eyepiece performance.

PLÖSSLS	
55mm	$160
40mm	80
32mm	80
26mm	65
21mm	65
17mm	65
13mm	65
10.4mm	65
7.4mm	65

BARLOW	
2.5x	65

Tele Vue 65°
WIDE FIELD EYEPIECES
A MAJOR NEW ADVANCE!

New 6-element design (pat. pend.) with a very wide 65° field. Significantly sharper than Erfles and König wide angle eyepieces. Field for field it rivals our Plössls. Almost essential for fast telescopes. Multi-coated.

40mm and 32mm Wide Field models have 2" barrels. 24mm and 19mm have 1¼" barrels and are parfocal with our Plössls. "First wide angle eyepiece with snap imaging." —John Vogt, New York

WIDE FIELDS	
40mm	$250
32mm	195
24mm	125
19mm	110

Tele Vue 82°
NAGLER EYEPIECES
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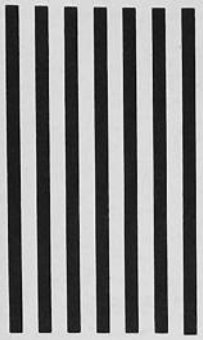

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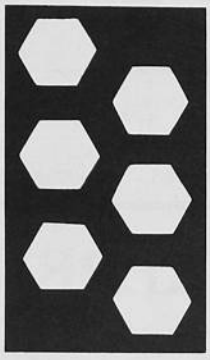

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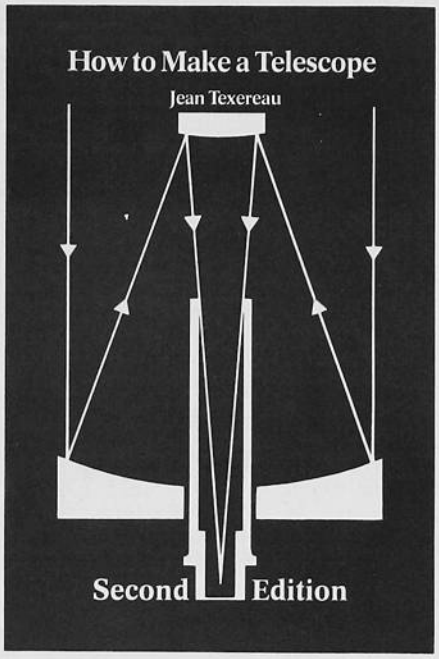

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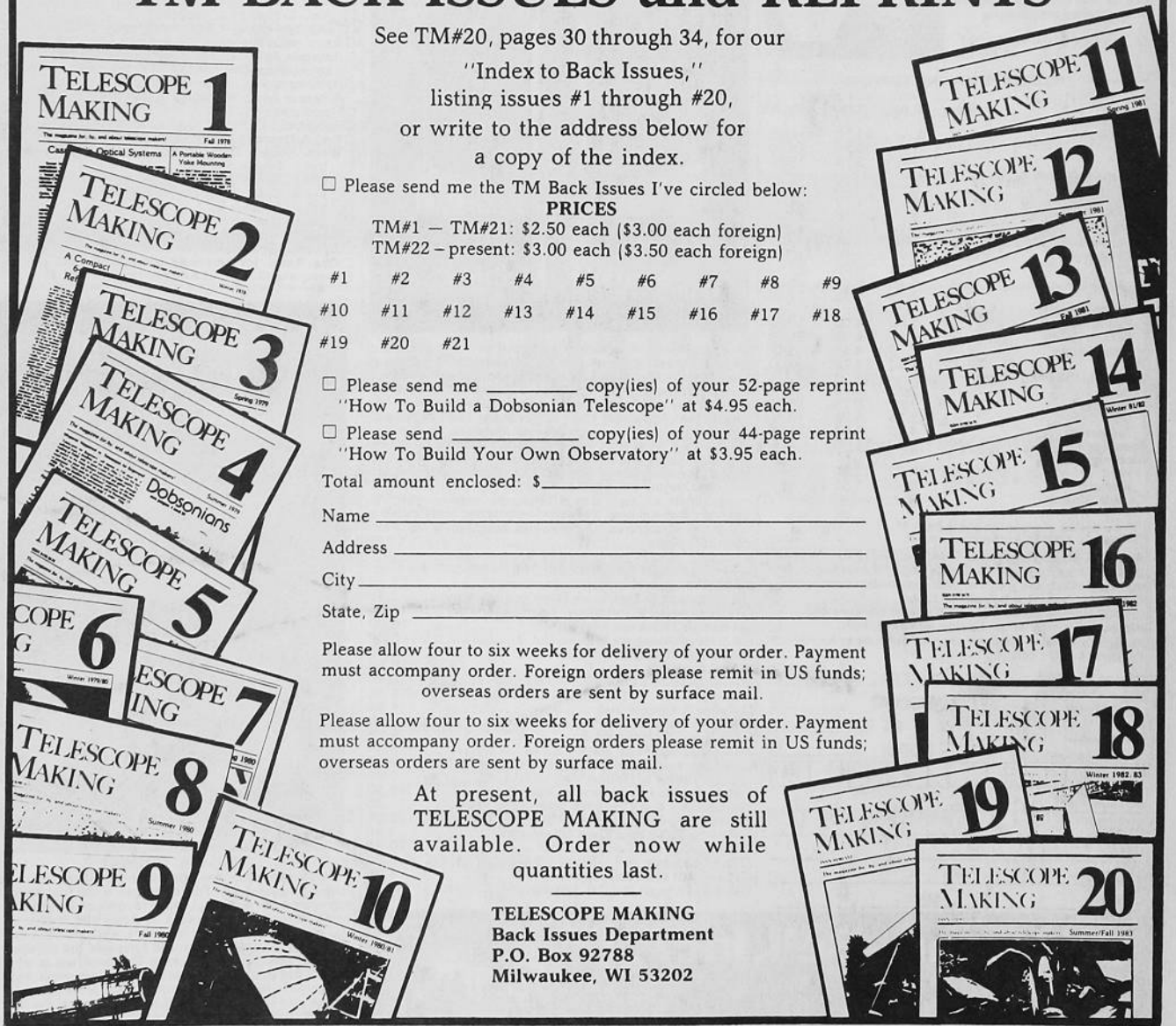

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